



These are our water pipes

Sand dams, women and donkeys
– dealing with water scarcity in
Kenya's arid and semi-arid lands

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Abstract

As climate change continues to alter the reliability and intensity of rainstorm events, and lead to higher evaporation rates many traditional water collection methods in Africa's arid and semi-arid lands are failing to provide water throughout the dry season. Sand dams, which are impervious concrete barriers built across ephemeral streams, are increasingly being used as an adaptation strategy to deal with water insecurity. This strategy requires community participation to construct the dam and management of catchment erosion in order to ensure the dam reaches maturity. A mature sand dam enhances the riverbed storage capacity through the accumulation of sand against the upstream side of the dam. This expansion of the riverbed reservoir allows water to be stored in the area that otherwise would have been lost downstream. The sand further protects the water by limiting the potential for evaporation, thereby ensuring availability of water throughout the year. A mature sand dam is additionally argued to improve the quality of water and build resilience through enabling ecological restoration, diversified livelihoods and the creation of social capital through the requirement of community participation.

Through the evaluation of five sand dam projects in five different Kenyan communities, this study evaluates the social factors and processes that contribute to the successful sand dam projects. Successful sand dam projects are deemed those in which the sand dam reaches maturity and in which social capital built during the construction phase enabled further development projects. Using qualitative research methods participants, non-participants and project leads voiced perspectives, successes and challenges in relation to sand dam adaptation strategies. The case studies illuminated the importance of community cohesion and drive, capacity building and follow-up from the implementing institutions. It was determined that these social factors are equal in importance to the proper construction and technical considerations of the concrete structure and are in fact the key factors in a dam maturing into a sand dam.

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I would like to extend my gratitude to my MES advisor and supervisor. To Deborah Barndt, my MES advisor, thank you for your calm direction and encouragement to follow my own path, your voice of reason brought this research into being. To Velma Grover, my MES supervisor, I will be forever indebted to you for seeing the possibilities and for your trust, inspiration, and guidance. Your friendship, expertise, and patience throughout this endeavour and during the long and arduous writing period always encouraged me.

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Foreword

This major paper and the course work preceding it were undertaken in partial fulfilment of the requirements for the degree of Master in Environmental Studies. The area of concentration, *Integrated Watershed Management for Resilient Landscapes*, explored within this degree focused on the connecting and life sustaining role of water and the ability of current water management approaches to effectively create resilient landscapes. Resilient, in this context, refers to the capacity of communities to draw on resources, such as financial, social, natural, enabling them to cope with and adapt to change. The components of my area of concentration sought to develop an understanding of the dimensions, challenges and conflicts associated with the use of natural resources, to enhance my knowledge and ability to use available tools and methodologies to properly manage our natural resources and lastly, to explore the literature for factors and processes that are deemed necessary to build resilient communities.

This paper and associated field work in Kenya built on the components outlined in my plan of study and served as an in-depth examination of watershed management in praxis. The exploration of the causes and dimensions of community vulnerability in each of the case studies corresponded to the first component, while the qualitative methods used further exposed me to tools available to researchers and managers and finally, identifying the factors that have contributed to successful sand dam projects and the building of a social capital foundation contributes to understanding of resilience building.

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List of Acronyms

ALRMP – Arid Lands Resource Management Project

ASALs – Arid and Semi-Arid Lands

CAAC – Catchment Area Advisory Committee

CCAA – Climate Change Adaptation in Africa

CSTI – Centre for Science Technology Innovations

ECA – Economic Commission for Africa

ENSO – El Nino Southern Oscillation

FAO – Food and Agriculture Organizations of the United Nations

GDP – Gross Domestic Product

GHF – Global Humanitarian Forum

GoK – Government of Kenya

GWP – Global Water Partnership

IISD – International Institute for Sustainable Development

IPCC – Intergovernmental Panel on Climate Change

IWRM – Integrated Water Resources Management

KDC – Kitui Development Centre

KMD – Kenyan Meteorological Department

Ksh – Kenyan Shilling

MDG – Millennium Development Goals

NAPA – National Adaptation Programmes of Action

NGO – Non-Governmental Organization

RWH – Rain Water Harvesting

SHG – Self-Help Groups

SSA – Sub-Saharan Africa

UNEP – United Nations Environment Programme

WHO – World Health Organization

WRMA – Water Resources Management Authority

WRUA – Water Resources Users Associations

WSSD – World Summit on Sustainable Development

WWF – World Wildlife Foundation

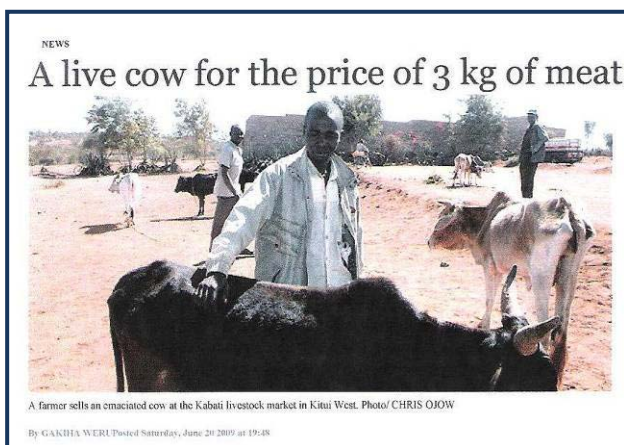


Figure 1. A sample of articles collected from local newspapers addressing water scarcity and drought in Kenya. (Top Left – Weru, 2009; Top Right – Wachira, 2009; Bottom – Makeni, 2009)

¹ 1 Canadian dollar is approximately equivalent to 76 Kenyan Shillings (Ksh or Sh)

1. Introduction

The fourth Intergovernmental Panel on Climate Change (IPCC) report (2007) states that 25 percent of Africa's population (200 million) are currently experiencing high water stress and that by 2020 between 75 and 250 million people are projected to be exposed to an increased water stress due to climate change. Among the areas most affected will be the arid and semi-arid lands (ASALs), which account for more than two thirds of the African landmass. These zones are extremely susceptible and vulnerable to water shortages and drought; receive an annual rainfall of below 700 mm; and support a population of over 400 million Africans (Darkoh, 1993; IISD, 2009). Climate change aggravates the existing problems of poverty, water and food insecurity.

Coping mechanisms for dealing with drought and variable rainfall are failing as rains have become more unpredictable and drought more frequent. The Government of Kenya (GoK) (2007) explains that in the past droughts used to occur every 10 years now the frequency is every 5 years.

Traditionally used water sources such as scoopholes in dry riverbeds and hand-dug shallow wells are drying during prolonged drought. Women can spend days in search of water during dry periods (Nissen-Petersen, 2006). Excellent Development (2007), an NGO dealing with water security in Kenya, states that "during drought women can spend 5-8 hours a day to collect 20 litres of dirty water, leaving little time for other activities".

Orientated with the premise that water security and water conservation needs to underpin any successful development initiative in ASALs, this study investigates the potential of sand dams as a strategy to increase the adaptive capacity of rural communities. Several studies have evaluated the physical and socio-economic feasibility of these structures (Borst and de Haas, 2006; Lasage et al, 2008; Quilis et al, 2009). They noted that the strategy increases the amount of stored water, reduces poverty and is cost effective, robust and simple to implement. However, the ultimate success of the strategy within an area has been linked to community organization and commitment. Lasage et al

(2008) reflect on this in the following:

more research needs to be done before sand dams can be up-scaled to other areas as adaptation to droughts. Besides the relative simplicity of the technique the commitment and organization of the community is a very important factor for the success. This must be taken into account when the feasibility of implementing the technique in other regions is explored

Research regarding factors that influence community motivation and organization has been far more modest.

For sand dams to be effectively implemented in other communities and by other institutions it is important to identify the necessary conditions that ensure success and how to develop and nurture these conditions. This study, thus, will explore the question: which factors contribute to the success of sand dam construction; its maturation; and more importantly the creation of a social capital foundation which can be a catalyst for other community based development activities? In order to pursue the above stated research goal, the following three objectives were sought:

1. To identify individual and community vulnerability to water scarcity associated with climate change and capabilities for dealing with said scarcity by focusing on the environmental, historical, social, economic, infrastructural/technical and political dimensions.
2. To evaluate the effectiveness of the sand dam development paradigm as an adaptation and development strategy.
3. To explore the factors and processes that constrain or contribute to the success of sand dam construction, longevity and its use as a catalyst for other development activities.

The intent of this paper is to present post-project reflections from involved communities; to stimulate stakeholder discussions and to identify ways that NGOs and governments undertaking sand dam development can improve their methodologies, practices, and follow-up. The overall aim is to contribute to more effective projects and community management of water resources.

1.1 Paper overview

This major research paper is organized into six chapters. Chapter two presents a review of the literature providing the rational and theoretical foundation for the present study and for the overall

promotion of improved water resources management, within which advances the uptake of adaptation strategies that increase water security. Literature reviewing the impact of climate change, the connections between climate, water and development in Africa, vulnerability assessments, adaptation and resilience all form the basis for advocating for holistic approaches to water management.

Chapter three provides context for the study. Background information relating to sand dam technology as well as country information and a detailed description of the individual case study locations is presented.

The following chapter, chapter four, outlines the range of qualitative methods employed for data collection such as household questionnaires, semi-structured interviews, focus group discussions and personal observation. Chapter five discusses the findings from both primary and secondary data collection. Chapter six summarizes the main findings and conclusions drawn from this study.

2. Literature Review

Rural water supply services, which support two thirds of the continent's population, remain inadequate across Africa (ECA, 2006). Approximately 65 percent of rural Africa does not have access to an adequate supply of water and 73 percent are without access to adequate sanitation (UNW Africa, 2003). The Global Environmental Outlook 2000 reported that 14 countries in Africa were subject to water stress (1000 to 1700 m³/person/yr) or scarcity (less than 1000 m³/person/yr) and that by 2025 this will increase to 25 countries² (Figure 2). At this rate the water and sanitation targets set

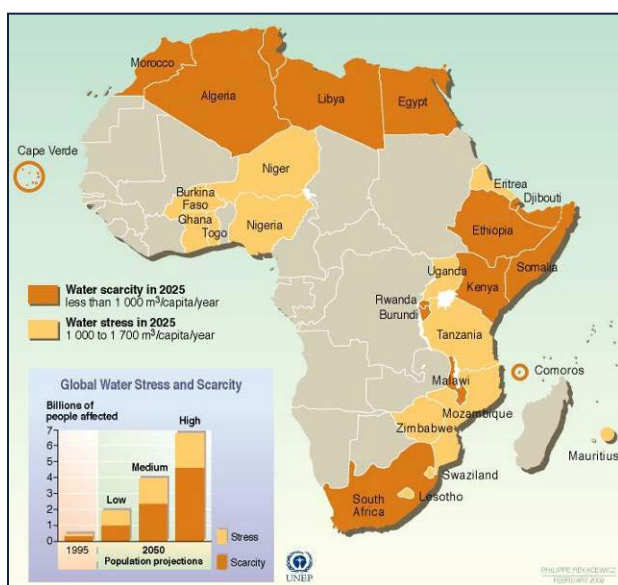


Figure 2. Freshwater Stress and Scarcity in Africa by 2025

(Source: United Nations Economic Commission for Africa (UNECA), Addis Ababa; Global Environmental Outlook 2000 (GEO), UNEP, Earthscan, London, 1999; Population Action International)

by international conventions will not be met in Africa. The Millennium Development Goals (MDGs) and the World Summit on Sustainable Development (WSSD) set actions to reduce by half the proportion of people without access to safe drinking water and without access to basic sanitation by 2015. The African Water Vision plans to reduce the number by 70 percent by the same year (ECA, 2006). Accessibility to

fresh water while innately invaluable also impacts and interrelates with many other goals

set out by the same international conventions. These goals such as eradicating poverty and ensuring food security, promoting gender equality, reducing child mortality and improving environmental sustainability are all interconnected and all depend on water.

² These estimates are based solely on population growth and do not consider the variability and effects of climate change.

On a continental level Africa has an annual average precipitation comparable to that of Europe or North America. This, however, disregards the temporal and spatial climate variability and the high rate of evaporation (UNWAfrica, 2003). Only 20 percent of the annual precipitation contributes to renewable water resources, reflecting the high losses of rainfall, in part caused by high evaporation rates (UNWAfrica, 2003). Africa's vulnerability to water scarcity is twofold, first as a result of a lack of services and management providing access to safe water and second as an inherent physical unavailability or variability of water. 'Apparent' water scarcity can occur in areas where there is plenty of water but it is being used inefficiently or wastefully (Falkenmark et al, 2009). Drivers of apparent scarcity can be high demand, pollution, land degradation and poor management (Falkenmark et al, 2009). Across Africa contamination of water resources from pollution, poor sanitation practices, sewage, solid wastes and invasive plants is increasing (UNWAfrica, 2003). Only 3.8 percent of Africa's internal renewable resources are being withdrawn reflecting that scarcity may in part be due to low levels of infrastructural development. The African Water Vision 2025 (2003) states that current institutional arrangements at local, national, and international levels are inadequate, and that finances for water resources are unsustainable. The vision further elaborates on the difficulties explaining that socio-economic development depends on the availability of water resources but that development of water resources depends on financial resources from economic development. 'Real' water scarcity resulting from the limited nature of the resources and the temporal and spatial variability is endemic in Africa's ASALs.

Climate change also threatens to exacerbate existing vulnerabilities to water scarcity and associated effects on development and food security. While only 4 percent of the world's total carbon dioxide is emitted by Africa, it is the continent most severely affected by climate change and it is reflected by mortality rate in Figure 3 (GHF, 2009). Some of the expected impacts are a decrease in arable land, especially within arid and semi-arid lands, and a potential 50 percent reduction in yields for rainfed

agriculture by 2020 (IPCC, 2007). Africa's vulnerability is not only due to the physical manifestation of climate change but also relates to Africa's low adaptive capacity.

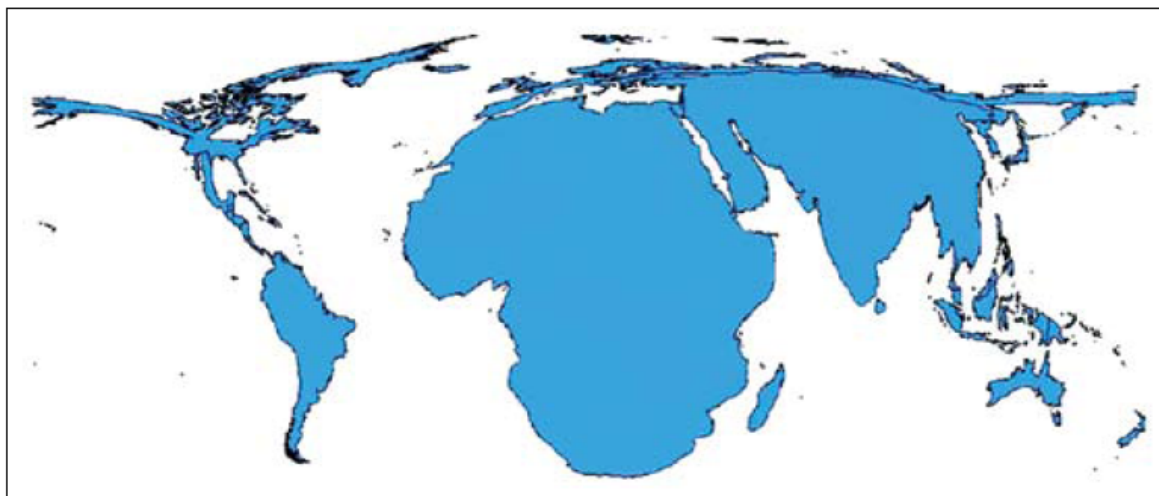


Figure 3. The world map reflecting mortality related to climate change

(Source: Climate Change and Global Health: Quantifying a Growing Ethical Crisis, 2007, Jonathan A. Patz, Holly K. Gibbs, Jonathan A. Foley, Jasmine V. Rogers, and Kirk A. Smith – Retrieved from Global Humanitarian Forum, 2009)

2.1 Climate change and water resources in Africa

There is general consensus among the scientific community that the world's climate is changing and at unprecedented rates. The IPCC (2007) reports that changes due to climate can now be observed in natural systems on all continents. In the last century, worldwide mean surface temperatures have increased by 0.6 ± 0.2 °C (IPCC, 2001). It was concluded with 90 percent probability that the increase in temperature is directly attributed to anthropogenic greenhouse gas concentrations (IPCC, 2007). As greenhouse gases continue to accumulate in the atmosphere, climate models are projecting an increase in global temperature of between 1.4 and 5.8 percent by 2100 (IPCC, 2001). In Africa the increase is expected to be 1.5 times the global mean, resting at an increase of between 3°C and 4°C by the end of the century (Eriksen et al, 2008). Climate and the hydrological cycle are inextricably linked. Bates et al (2008) explain that global warming has impacted the hydrological cycle through changes in precipitation patterns, extreme events, rates of evaporation, increased levels of atmospheric water vapour and changes to soil moisture and runoff. Sadoff and Muller (2009) affirm

that “water is the primary medium through which climate change will impact people, ecosystems and economies”. In fact, the IPCC working group II (2008) state that “water its availability and quality will be the main pressure on, and issues for, societies and the environment under climate change” (Bates et al, 2008).

Overall, impacts on freshwater are expected to be negative. Climate change is predicted to result in more areas being under water stress than those foreseeing a greater quantity (IPCC, 2007). And even those expecting more, may have to contend with increased temporal variability and more intense events. Within the seven climatic zones distinguished across Africa, there are also elevation changes, other localized variables and seasonally variability, that all impact climate. Thus, just as globally, predicted impacts are not uniform across the continent and are associated with a considerable amount of uncertainty. Generally, all projected changes are represented as a range of possible scenarios, this uncertainty results from an incomplete understanding of the climate system (in Africa this also relates to lack of data) and unknowable future level of climate forcings (such as greenhouse gas levels). The following section presents the predicted impacts of climate change on Africa’s water resources.

2.1.1 Rainfall

Rainfall patterns in Africa are known to exhibit spatial and temporal variability, which is expected to increase. Overall the IPCC (2007) projects that rainfall will increase in high latitudes and parts of the tropics and decrease in some subtropics and lower mid-latitude regions (Bates et al, 2008). In Africa, the Eastern regions are expected to experience increased rainfall and southern regions a decrease. However, it is noted that even in areas where countries will receive more rainfall, increased precipitation variability is likely to offset this benefit (Bates et al, 2008).

The proportion of rainfall is a lower concern in Africa where a large percentage of the population relies on rainfed agriculture. The greater concerns are the timing of the onset of rains and the

distribution of rain throughout the growing season (Simms and Reid, 2005). Both of which are expected to be more unreliable with climate change (IPCC, 2007).

Africa is already strongly affected by drought. The increased precipitation intensity and variability, expected with climate change will lead to great risks of floods and droughts (IPCC, 2007). The increases in temperature and higher evaporation rates strengthen the chances of more intense rainfall, which coupled with the high rates of land degradation, will result in flash flood events (Sadoff and Muller, 2009). These events often result in landslides, soil erosion, water contamination, and damages water and power infrastructure (Osbaahr et al, 2006).

Temperature predictions for the region are fairly strong however the use of the global climate models to predict changes in rainfall are less certain due to poor or omitted representation of two key variables. First, the El Nino Southern Oscillation (ENSO) is deemed one of the key controlling factors for rainfall in Africa but is generally poorly represented within the models. Second, most models omit to represent possible changes in land-use or land cover, dust and aerosols biomass (Hulme et al, 2001)

2.1.2 Runoff and Streamflow

Similar to precipitation pattern, the IPCC (2007) predicts that river runoff will increase in high latitudes and in some wet tropics and decrease over some dry regions in the tropics and in mid-latitudes (Bates et al, 2008). Semi-arid and arid regions, where evaporation rates are expected to increase, will suffer from a decrease in water resources. Sadoff and Muller (2009) explain that all “other things being equal, with the drier ground and increased evaporation of a hotter climate, less water will run off to the rivers or percolate into the deeper aquifers”. It is estimated that areas of Sub Saharan Africa (SSA) could see a reduction in stream flow by 50 percent (Sadoff and Muller, 2009).

2.1.3 Groundwater

Groundwater represents a challenge in all parts of the world as it is the water source that is the least monitored and most difficult to manage. Groundwater is an important source of water for many countries and especially in rural areas that rely on hand-dug shallow wells and boreholes. The African Water Vision 2025 (UNWAfrica, 2003) estimates that 75 percent of Africa's population relies on groundwater sources for drinking water. The Global Environmental Outlook (2000), also provides the examples of Botswana and Namibia, where 80 and 40 percent, respectively, of its water for livestock and domestic uses are from groundwater sources (Clarke, 1999).

While there are few assessments on the impact of climate change on groundwater resources, there replenishment will undoubtedly be affected. Especially in warmer and more arid climates, where the opportunities for rainwater to infiltrate into aquifers will be lower. Sadoff and Muller (2009) explain that “where soils are often dry, the first rain that falls is absorbed by the top layers of soil; if a dry period follows, much of this moisture will be used by vegetation or evaporate back into the atmosphere”. Groundwater is replenished when an accumulation of rainfall has been allowed to remain for a period of time in one place, saturating the soil layers and the remainder being able to percolate to the aquifer.

In addition, more groundwater sources in proximate location to coastal areas are expected to be affected by salinisation as sea levels rise (IPCC, 2007). Salinisation of groundwater is also likely to occur in Arid and Semi-arid areas, due to high evaporation.

2.1.4 Lakes levels

Climate change is influencing lake water levels and productivity across the continent. Both Lake Victoria and Lake Chad, which each support a livelihood of more than 30 million people, have been experiencing drastically receding water levels (Awange et al, 2008; Virgo, 2009). Lake Chad which in 1964 stretched over an area of 25,000 km² now covers less than 1000 km² (LCBC, 2008; Virgo,

2009). In the last five years Lake Victoria's water levels have dropped 1.1 m below the 10 year average (Awange et al, 2008). While both lakes and others on the continent are subject to high demand, climate change cannot be ignored as a contributing factor to fluctuating lake levels. Lake Victoria, for example, is 80 percent replenished through direct rainfall. Higher temperatures are also accelerating evaporation rates.

Climate change not only threatens lake levels but also productivity. The rising lake temperatures are negatively impacting fisheries (IPCC, 2007 [9.4]). According to the Food and Agriculture Organization (FAO), species diversity in Lake Chad has reduced and the fishery resources has dropped by 60 percent (Virgo, 2009).

2.1.5 Water Quality

Water quality is expected to be affected by several compounding factors. Freshwater ecosystems have the ability to assimilate, dilute and remove a certain amount of waste. However, with the expected reduction in runoff, the amount of waste that can be absorbed will decrease and new regulations and enforcements will be needed to protect the ecosystem (Sadoff and Muller, 2009). In addition with the increase in intensity of rainfall events, water quality is expected to suffer from the enhanced transport of dissolved pollutants (such as pesticides) and suspended solids due to erosion (Bates et al, 2008).

2.1.6 Glacier retreat and mountain ecosystems

Mountains are often described as 'water towers' and are the headwaters for the majority of rivers worldwide. In Africa three of the largest mountains and their respective supply of water are being threatened by climate change. In the last century glaciers on Mount Kilimajaro have been reduced by 80 percent (IPCC, 2007). However, glacier retreat is not the only impact on water resources, ecosystem shifts causing increased occurrences of forest fires have reduced the area of 'cloud forest'. The loss is equated to 25 percent reduction in 'fog water' or water for 1 million people living on the mountain (IPCC, 2007). Both Mount Kenya and the Rwenzori Mountains are also experiencing

glacier retreat, which will reduce the supply of water for 7 and 2 million people respectively (Kiteme et al, n.d; WWF, 2008).

2.2 The Web of Connections – The impact of water scarcity and climate change on development

“Hungry mouths depend on water for agriculture which provides not only the food to eat but the income with which to buy it....” (FAO Water for Food pamphlet, March 2000 – as quoted in Falkenmark et al, 2001)

Box 1. Africa: Up in smoke 2? references the IPCC (2001) and identifies six conditions that cause Africa to be particularly vulnerable to climate change (Magrath, 2006):

1. Water resources, especially in international shared basins where there is a potential for conflict and a need for regional co-ordination in water management.
2. Food security at risk from declines in agricultural production.
3. Natural-resources productivity and biodiversity at risk.
4. Vector- and water-borne disease, especially in areas with inadequate health infrastructure.
5. Coastal zones vulnerable to sea-level rise, particularly roads, bridges, buildings, and other infrastructure that is exposed to flooding.
6. Exacerbation of desertification by changes in rainfall and intensified land use.

Water is vital to all development activities and poverty reduction strategies across Africa. Changes in rainfall timing and reliability, water runoff and availability will affect all sectors. The IPCC (2001) declared that Africa will be the region most vulnerable to the impacts of climate change due to the widespread poverty, reliance on natural resources and limited adaptation capabilities (Box 1). The following section outlines how water plays a role in development in three fundamental ways. First, water is a key production unit in agriculture, industry and alternative livelihood ventures. Lack of water therefore limits food and income security. Second, as water becomes scarce time spent in search of water, is time that

could be spent attending school, completing domestic chores and on other income generating activities. Third, lack of adequate fresh water impacts household health, which in turn limits the availability of labour to grow food, for employment and other development projects.

In Africa reducing poverty and ensuring food security is directly linked to agriculture. It is the largest contributor to GDP and is primary source of income for more than 65 percent of the population (Ludi, 2009; Global Humanitarian Forum, 2009). Sources of food in SSA predominately come from rainfed

agriculture, which is used on more than 95 percent of the cropland (FAO, 2002). As rainfall is extremely variable and increasingly unreliable, it is severely limiting production. The IPCC (2007) reports that agricultural production across Africa will be impacted by reductions in the length of the growing season and yield potential. It is estimated that climate change may cause an additional 80-120 million people to experience food insecurity, of which 80 percent are expected to be African (IPCC, 2001). While there are other ways of ensuring food security such as through food imports or ‘virtual water’³, most individuals do not have the cash to access the produce available in the markets. The African population is highly dependent on the natural system for their livelihood. Water is essential for the functioning of all ecosystems, including crop lands and forests, which provide a multitude of ecosystem functions and services. Climate change and other stressors continue to negatively impact the fragile ecosystems, putting the population at risk. Freshwater ecosystems generate a key source of revenue through fisheries. Temperature changes, increased runoff, pollution and catchment degradation are causing deterioration of Africa’s freshwater ecosystems. Lake Victoria has experienced a loss of over 100 fish species since the 1960’s due in large part to pollution (UNEP, 2006; IPCC, 2007). In addition, saltwater intrusion into lagoon and estuaries will negatively affect fisheries in coastal regions. Further impact on mangroves and coral reef will result in a decline in tourism, as will other potential species loss. For example, one of the large game parks in South Africa, the Kruger park, estimates that they may see a 66 percent species loss due to climate change (IPCC, 2007). In rural areas other livelihood activities such as brick making, construction, bee keeping, beer brewing and nurseries are also all affected by water stress.

The daily searches and long waits for water further impact development. African women can walk up to 20 km in dry periods in search of water (Lasage et al, 2008). It is estimated that 70 – 80 percent of agricultural workers are women, thus time spent fetching water impacts household food security and takes time away from domestic duties and other income generating activities (Global Humanitarian

³ Virtual water represents a potential adaptation strategy whereby countries can import water by importing commodities that require large amount of water to produce.

Forum, 2009). It is predominantly women and young girls involved in walking the long distances and hauling water. This entrenches gender inequalities, as the young girls are regularly required to stay home from school to help search for water. Women are seen as most responsible for household well being, the provision of which includes ensuring sufficient water is available for consumption (drinking and cooking), hygiene (washing, bathing, cleaning) and for productive uses (watering livestock and household gardens) (Thompson et al, 2001). When water is scarce not only does it affect the frequency and adequacy of which these activities can be accomplished, it also impacts the amount of time that female household members have to implement them. Scarce water resources, in turn, also influence communities' abilities to continue with development projects, such as rehabilitating degraded environments. For example, a Kenya women's group, Tei Wa Aka Ma Musyi Women group, explained that when the rains fail there is not enough water to sustain their tree nursery and they are thus unable to plant trees to protect their watershed (personal communication, March 30, 2009). This women's group, who also sell their trees for a profit, struggles to balance time for the project when food and water are scarce.

Health impacts of climate change in Africa are complicated by a variety of factors including poverty, poor nutrition, other disease burdens, poor access to drug treatments and land use changes (Simms and Reid, 2005; IPCC, 2007). The following quote from *Drawers of Water*, illustrates some of the challenges to health brought by rural water insecurity.

"An African housewife gets up in the morning and soon begins to fetch water. She walks through the thicketed savannah to the water source. This is the habitat of tsetse flies and she is exposed to their unpleasant bites and the risk of sleeping sickness. She reaches the water source in a valley bottom and has to wait her turn. This is the habitat of disease-bearing mosquitoes and of a different tsetse fly more efficiently transmitting sleeping sickness. The stream contains snails transmitting bilharziasis if it is sluggish, or breeds the vectors of onchocerciasis if it is rapid, or may contain guinea worm larvae if it is a mere muddy hole. She collects the water, which today bears a highly dilute load of human excreta and may contain typhoid bacilli or hepatitis virus. She returns, past the tsetse flies, to her home...She prepares the family's main meal. The scarcity of water discourages the washing of hands before the meal

and makes washing-up after the last meal perfunctory. Some decayed food may be left on the utensils. Some unboiled water is drunk by her thirsty family, who pick up the germs from it”
(White et al, 1972)

There are a range of health problems associated with climate change and water resources, such as increases in vector-borne, water-borne, water-wash and food-borne diseases and increases in malnutrition.

Worldwide, malaria is the cause of 300 to 500 million deaths and in Africa results in 1.3 percent stagnation in economic growth each year (UNEP, 2005 as quoted in Simms and Reid, 2005). Climate change causing changes in rainfall, humidity and temperature has altered the spatial distribution and rate of development of the malaria vector species, anopheles mosquitoes (IPCC, 2007 [9.4]).

Increases in temperature are making highland areas in East Africa which were previously malaria free suitable habitat for mosquitoes. Recently, highland areas of Kenya, Ethiopia, Rwanda and Burundi have experienced a resurgence of the disease (Conway, 2009).

In *Drawers of Water* (1972) the researchers explain that quantity as well as quality of water is intimately linked to the health of household members. David Bradley in the 1970's classified water related diseases by their transmission routes (as quoted in Thompson et al, 2001). The traditionally known causes of water related illnesses are waterborne diseases (typhoid, cholera and diarrhoeal diseases) caused from the consumption of contaminated water (Rosen and Vincent, 2001). The World Health Organization (WHO) (2004) recorded that 3, 900 children die every day due to waterborne diseases (As quoted on World Water Council website <http://www.worldwatercouncil.org>). Another pathway, less considered, but more likely to be the cause of faecal oral diseases is water-wash transmission. This route, such as through hands, food, and dishes, is the result of households not having access to enough water, causing bathing, washing dishes and cleaning clothes to be secondary priorities. Primary treatments of illness for over 80 percent of the population of developing countries are through the use of traditional medicines (WHO – as quoted in Simms and Reid, 2005). These

lines of defence are being threatened by climate change which is altering the habitats of many medicinal plants.

2.3 Vulnerability

In order to reduce the threats on water availability imposed by climate change, as outlined in the previous sections, research is increasingly focussing on vulnerability-led approaches. Africa's susceptibility to hardships and catastrophes resulting from water scarcity is complex due both to the physical exposure to hazards of climate variability and change and to the sensitivities and low adaptive capacity of the continent's population. The underlying factors of high dependence on inadequate natural resources and high levels of poverty limit the choices available for coping and adapting to climatic hazards.

2.3.1 Defining Vulnerability

Definitions of vulnerability have been influenced by many fields and as a result they are often conflicting. Three competing interpretations have been described in the literature (Cutter, 1996; Kelly and Adger, 2000; Thornton et al, 2006).

The first is the 'end point' approach. The IPCC in 1995 defined vulnerability as "the extent to which climate change may damage or harm a system; it depends not only on a system's sensitivity but also on its ability to adapt to new climatic conditions" (as quoted in Kelly and Adger, 2000). This definition reflects the belief that vulnerability is the harm that remains after considering both the susceptibility to the possible future scenarios and the mitigating influence of adaptation. In the 'end point' approach hazard is viewed as the main problem. Interventions thus focus on climate change and create mitigation and adaptation measures that directly act to lessen the impacts of the hazard.

The 'starting point' approach is the second interpretation. This view focuses on coping responses and defines vulnerability as "the capacity to cope with, resist, and recover from the impact of a natural hazard" (Blaikie et al, 1994 as quoted in Kelly and Adger, 2000). Vulnerability is the result of

inherent characteristics of the system (Adger and Kelly, 1999). Exposure to the hazard is considered separately from this definition, instead vulnerability is viewed as a social construction not a biophysical one (Cutter, 1996).

In the third, ‘focal point’ approach vulnerability is viewed as a hazard of place. Focusing on a particular geographic place, three components of vulnerability are considered: exposure, sensitivity and the capacity to adapt (Eriksen et al, 2005; Kelly and Adger, 2000). This is the conception of vulnerability used in this study and is defined by Smit and Wandel (2006):

Vulnerability of any system (at any scale) is reflective of (or a function of) the exposure and sensitivity of that system to hazardous conditions and the ability or capacity or resilience of the system to cope, adapt or recover from the effects of those conditions

2.3.2 Vulnerability Analysis

Assessments of vulnerability are complex, as the determinants are dynamic and vary over space and time. Smit and Wandel (2006) recognize that “what is vulnerable in one period is not necessarily vulnerable in the next, and some exposures and sensitivities develop slowly over time”. Multiple frameworks have been used to assess vulnerabilities, each reflecting one of the definitions. The multiple frameworks and analyses in the literature identified several commonly used dimensions of vulnerability. These dimensions, namely environmental, historical, social, economic, infrastructural and technical, and political parameters, are presented separately but are in fact intertwined with each other. While an evaluation of a system occurs at a particular time and scale (e.g. community) it is recognized that vulnerabilities may be constrained or facilitated by factors and processes occurring outside the system of analysis. For example analyses involving only the local scale would omit national political processes such as the formulation of adaptation policies or decisions regarding property rights (Adger et al, 2004; Kelly and Adger, 2000). Similarly, investigations considering collective community vulnerability might not distinguish individual or household vulnerability (Adger and Kelly, 1999).

The environmental dimension evaluates a system's biophysical endowments (such as land cover type and percentage, rate of deforestation, water resources, levels of biodiversity etc). In addition, this dimension which includes climate would identify a systems potential exposure to present and future climate related hazards. The resilience of the natural environment is also considered by, for example, taking into consideration ecological health. For example, degraded land is more susceptible to drought as soil infiltration capacity decreases, degraded land also increases the impacts and likelihood of flash floods as the natural flood control has been removed (Moberg and Galaz, 2005).

Temporal scales are addressed through analyzing historical dimensions of vulnerability. Historical evaluations focus on past processes that have contributed to current distributions of power, access to and control over resources. This approach begins by asking how the current situation manifested. Past policies that may have marginalized certain population groups, caused migration to sensitive areas or resulted in loss of cultural practices and coping strategies are examples of historical legacies that would influence vulnerability.

Social dimensions of vulnerability are complex and result from a multitude of factors. Parameters include class, gender, culture, religion, psychological dimensions, community structure, and demographics. Women are disproportionately involved in resource dependent activities, such as fetching water and gathering fuel wood and are therefore more vulnerable to climate related hazards (Adger et al, 2007; Simms and Reid, 2005). Differences between households and individuals in terms of class, gender and age can impact access to education, resources, and the level of acquired skills. All of which influence vulnerability (Eriksen and Kelly, 2007).

Psychological dimensions and religion⁴ that influence awareness, perceptions and understanding of risks within a system shape social vulnerability by influencing community motivation to adapt or take precautionary measures against hazards (Adger et al, 2007; Grothmann and Patt, 2005). Attitudes

⁴ For example, communities in Bangladesh believe that floods, tornadoes and cyclones are acts of God and that they should not do anything (Schmuck, 2000 as quoted in Grothmann and Patt, 2005).

such as dependence and fatalism negatively influence proactive and adaptive measures, whereas community cohesiveness and the existence social and kinship networks can increase coping strategies and lessen vulnerability⁵ (Adger et al, 2007; Eriksen et al, 2007; IFRC, 1996; Van Aalst et al, 2008).

Social and economic parameters of vulnerability are inherently overlapped. Social indicators such as access to education and resources underpin economic vulnerability. Gender also influences economic advantages as women in developing countries are limited by insecure land tenure (Adger et al, 2007).

Economic vulnerability refers to a population's ways and means of generating income and its susceptibility of being stressed or disrupted by a perturbation, such as a climate related disaster.

Economic activities that depend on natural resources such as fisheries and farming are highly susceptible to global environmental change. The diversification of livelihoods and use of alternative livelihoods can diminish economic vulnerability as it provides options for continued income generation during a disturbance (Adger et al, 2007; Moberg and Galaz, 2005). Adger et al (2005) when examining vulnerability of small-holder farmers in Kenya and Tanzania noted that farmers who partook in other activities were less vulnerable during drought. Economic vulnerability is also influenced by infrastructure (or lack of) and poor policies.

Infrastructural and technical dimensions of vulnerability are largely attributed to the presence, absence and robustness of roads, buildings, health care and access to information and communication networks and technology. In the water resources sector this may be related to the water supply infrastructure such as the number of households with piped water or the number of shallow wells. Adger et al (2007) explain that both access to information and technology will reduce vulnerability as information, such as weather forecasts, can facilitate better timing of planting and other weather sensitive activities. Access to technology such as rainwater harvesting, desalinization or use of silver

⁵ For example Tompkins and Adger (2004) showed that strong social networks and trust within the Buccoo Reef region in Tobago led to reduced vulnerability to the impacts of the coastal hurricane regimes. Cultural traditions, such as food sharing in Canada's Northern communities, can reduce negative impacts of hazards, however ethnic tensions and conflict can magnify impacts (Eriksen and Kelly, 2007; Ford et al, 2006).

water, improved seed varieties and farming techniques all contribute to coping and mitigating vulnerabilities.

Political dimensions of vulnerability are less visible and include underlying factors determining power, entitlements and access to resources. The parameters include institutional arrangements and legislation, such as policies, acts and regulations. Corrupt, top-down, centralized institutions increase vulnerability. Polycentric and multilayered institutions are believed to facilitate more appropriate decision making and more accountable authorities, which are thus better able to adapt to changing conditions and manage systems more sustainably, thereby reducing vulnerability (Anderies et al, 2006). Political arenas, through formulation of policies, acts and regulations create enabling environments or ‘the rules of the system’. These policies such as national development strategies, disaster management plans, climate change adaptation policies etc formulate which vulnerabilities will be addressed and how, and create vulnerabilities by ignoring key sectors. For example water legislation will determine entitlements and user responsibilities (Cap-Net, 2008).

Knowing in which ways a system is sensitive to or capable of responding to climate related hazard allows one to see points at which interventions may decrease vulnerability and increase a system’s resilience. The manner in which vulnerability is defined and assessed influences the types of adaptations that are promoted. End-point approaches seek to answer “what can be done to protect the population?” (Eriksen and Kelly, 2007). In contrast, starting point approaches seek to answer “what can be done to strengthen people’s own capacity to respond and adapt?” (Eriksen and Kelly, 2007). Defining vulnerability through a focal point approach incorporates both questions and therefore promotes a variety of adaptation options.

2.4 Adaptation to Climate Change



(Source: Cap-Net, n.d)

The concept of adaptation originated in the natural sciences, where it was defined as “the development of genetic or behavioural characteristics which enable organisms or systems to cope with environmental change in order to survive and reproduce” (Smit and Wandel, 2006). Within the human sciences, adaptation originated in anthropology and cultural ecology, as the study of how cultures adjusted or introduced methods in order to cope with the natural environment. It has since been used in several other social science discourses including, natural hazards, political ecology and food security. Within the climate change field adaptation is defined as (Smit and Pilifosova, 2001):

adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. This term refers to changes in processes, practices and structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate.

Smit et al (1999 – as quoted in Smit and Pilifosova) outline the relationship between climate change and adaptation (Figure 4). They show that adaptation can be classified into autonomous and planned adaptation. Autonomous adaptations are reactive, natural adjustments, made by species, ecosystems and people. Societies in the past have modified their activities and processes in response to climatic stimuli. Unfortunately, Smit and Pilifosova (2001) explain that the rates of change, coupled with other environmental stressors and high levels of vulnerability are causing autonomous adaptation to be insufficient to mitigate the negative impacts of climate change and variability (Adger et al, 2003; Smit and Pilifosova, 2001). Interventions are required to decrease a system’s sensitivities and increase its ability to adapt and cope with change. Unlike most species and ecosystems, humans have

the conscious ability to anticipate changes, forecast and plan for the future. Planned adaptations are therefore policies, programs and other measures implemented to reduce current vulnerabilities and to manage present and future climate related hazards.

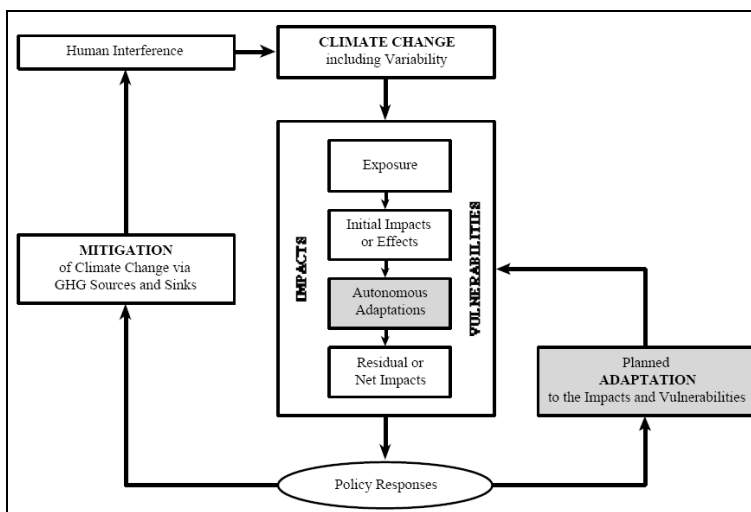


Figure 4. Places of adaptation to climate change
(Smit et al, 1999 referenced from Smit and Pilifosova, 2001)

2.4.1 Types of Adaptations

Adaptation strategies have been categorized in many ways and with many typologies (Smit et al, 2000). Smit and Wandel (2006) explain that forms of adaptations can be classified according to the timing relative to the stimulus, the purposefulness or intent, spatial scope and form (Table 1)

Table 1. Bases for characterizing adaptation strategies
(Smit et al, 1999 -as quoted from Smit and Pilifosova, 2001)

General Differentiating Concept or Attribute	Examples of Terms Used	
Purposefulness	Autonomous Spontaneous Automatic Natural Passive	Planned Purposeful Intentional Policy Active Strategic
Timing	Anticipatory Proactive <i>Ex ante</i>	Responsive Reactive <i>Ex post</i>
Temporal Scope	Short term Tactical Instantaneous Contingency Routine	Long term Strategic Cumulative
Spatial Scope	Localized	Widespread
Function/Effects	Retreat - Accommodate - Protect Prevent - Tolerate - Spread - Change - Restore	
Form	Structural - Legal - Institutional - Regulatory - Financial - Technological	
Performance	Cost - Effectiveness - Efficiency - Implementability - Equity	

Types of adaptation can be determined by individual, community or institutional choice options (Burton et al 1998; Smit and Pilifosova, 2001; Smit et al, 2000; Kates 1985 – as quoted in de Loë et al, 2001). Five choice options, with examples for the water resources sector, are distinguished below:

1. *Accept losses* – this adaptation represents the baseline response of ‘doing nothing’. Losses can be borne by the individual or shared by a community or group that does not have the capacity to adapt. Examples include insurance and public or international relief (Burton et al, 1998). In addition, Burton et al (1998) remark that in traditional societies there are many mechanism that facilitate sharing the loss.
2. *Prevent or modify effects* – the aim of this adaptation measure is to prevent the consequences of climate change or to attempt to control the threat itself. Strategies in this category may be structural or technological, institutional, legislative, regulatory or financial. In relation to drought structural changes and technological strategies might be to explore water harvesting options such as sand dams or the use of silver water through desalinization (Falkenmark et al, 2001). Institutional or management measures might be to facilitate leak detection programmes to prevent unnecessary loss of water (de Loë et al, 2001). Legislative options might include virtual water policies whereby certain products requiring large amounts of water to grow or manufacture are imported from countries with more per capita water availability.
3. *Change uses and/or locations* – when activities or practices are recognized as no longer being viable (either because too risky, too expensive, or not possible) in the face of climate change. Examples would include recalling unsustainable water permits or implementing land use and zoning plans that disallow certain activities. Another example would be re-using recycled water or using wastewater for agriculture (de Loë et al, 2001).
4. *Research* – adaptations which involve investment in further research into impact of climate change, new technologies and new methods. For developing countries, the process of completing their National Adaptation Programmes of Action (NAPA) involves identifying vulnerabilities and options for dealing with climate change.

5. *Educate, inform and encourage behavioural change* – these responses involve the dissemination of information which aims to increase individual and community behavioural changes. The use of downscaled forecasts to influence planting as well as the use of educational campaigns to promote conservation and efficient use of water are examples.

Generally, strategies within the water resources sector seeking to address the increased uncertainty, variability and extreme climate events have been categorized as either ‘hard’ or structural and ‘soft’ or institutional adaptations. Investments and focus on both categories recognizes that vulnerabilities result not only from biophysical parameters but also from social, economic and political challenges (Sadoff and Muller, 2009). ‘Hard’ investments include strategies that seek to capture and control water. These measures focus on the supply side of water resources management and options can vary from large scale dams to small-scale rainwater harvesting or to wastewater treatment facilities. ‘Soft’ option investments include all the institutional⁶ measures and can influence both the supply and demand side of water resources management. Some examples include use of restrictions, education and land use planning. Several potential institutional and structural/technical interventions have been identified by the NAPAs prepared by developing countries (Table. 2).

Table 2. Adaptation Interventions in the water sector (Source: modified from Nicole and Kaur, 2009)

Type of Intervention	Intervention
Institutional	<ul style="list-style-type: none"> ○ Mobilisation and integrated water resources management project ○ Implementation and management of water management associations ○ Contribution to better knowledge of surface water regimes ○ Institutional strengthening of water resources sector
Technical/Structural	<ul style="list-style-type: none"> ○ Rainwater Harvesting ○ Groundwater recharge for irrigation wells ○ Stabilisation of river dynamics and water courses ○ Development and Improvement of small-scale and Community Irrigation systems

⁶ Institutions are viewed as not only formal organizations but also as the rules governing how individuals relate to each other. Sadoff and Muller (2009) describe institutions as including “informal coordination activities, information gathering and collation, setting of rules through legislation or cooperation and the monitoring and regulation of compliance with them.

2.4.2 Evaluating Adaptation Strategies

From the literature and speaking with proponents, the following criteria were derived as characteristics of appropriate adaptations in the water sector. Adaptation strategies should be no regrets measures, improve equitable access to fresh water, reduce socio-economic vulnerabilities, minimize environmental impacts, be cost-effective, and feasible (to implement and longevity).

The *no regrets* criterion emphasizes that strategies should be selected that in addition to adapting to climate change address other existing problems or provide other benefits (Smith et al, 1996, de Loë et al, 2001). This criterion forces the recognition that there are numerous uncertainties associated with climate change and that strategies should reflect this.

Improving equitable access to fresh water involves making strides to ensure water security. Defined as “the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks”, water security relies on availability, ability to access (which can be affected by entitlements and geographic location) and quality (Sadoff and Muller, 2009; Smit and Pilifosova, 2001). Measures that improve water security may focus on increasing supply, improving quality or minimizing conflicts over the resources.

Reducing socio-economic vulnerabilities is an important and fundamental part of adaptations (de Loë et al, 2001; Kelly and Adger, 2000). Adaptation measures should be evaluated on the likelihood of the strategy increasing vulnerabilities or providing opportunities. For example strategies that encourage livelihoods that requires large amounts of water in regions that are prone to drought, should not be adopted. Similarly if the adaptation measure fails to consider equity in water allocations then socio-economic vulnerability of some may be increased.

Water management strategies aiming to adapt to climate change need to also be considered for their *impact on the surrounding environment* (de Loë et al, 2001). Those measures that may ultimately put

more pressure on natural resources and negatively impact the health of ecosystems should be avoided as they increase the vulnerability of the entire system.

De Loë et al (2001) explain that *cost-effective* measures are economically efficient and generally inexpensive to implement. The economic efficiency relates to the benefit to cost ratio, which for an effective strategy should be high indicating that the benefit outweighs the cost. Inexpensive strategies are promoted as there is still considerable uncertainty surrounding how climate will change. In addition for the developing world, inexpensive strategies are more likely to be able to be pursued.

Feasibility of an adaptation relates to two qualities. First, is the implementation of the strategy possible or are there barriers to its execution. Smith et al (1996) presented four broad areas where potential barriers could exist: institutional, such as are there legal constraints; social and cultural barriers; market, such as availability of capital; and technological. Measures that have been previously implemented provide an indication of strategies that will be accepted. The second part of the feasibility criterion refers to the long term feasibility or longevity of the adaptation strategy. This screening criterion evaluates whether the measure is sustainable in the long run. Answering the question will the strategy stand the test of time?

The criteria help evaluate and compare the strengths of the different adaptation measures. Those strategies that adhere to several of the criteria serve to improve adaptive capacity and the resilience of a system.

2.5 Resilience and Adaptive Capacity

The recent usage of the resilience ‘way of thinking’ in sustainable development and climate change fields has influenced how professionals advocate managing our systems. There is a shift from optimization and growth to one that promotes flexibility and nurturing of the requirements for systems to be able to recover, adapt and develop. The resilience alliance (www.resalliance.org) identifies that resilience of Social Ecological Systems has three defining characteristics (a) the

amount of change the system can undergo and still retain the same controls on functions and structure (b) the degree to which the system is capable of self-organizing, which speaks to the number of available options for reorganization in the face of disturbance (diversity) and (c) the ability to build and increase the capacity for learning and adaptation. The last characteristic defines adaptive capacity or the ability of actors in a system to influence resilience (Walker et al, 2004).

The resilience lens is appropriate for climate change research as it is fundamentally focused on dealing with uncertainty. There are several levels of uncertainty within the climate change debate. Some examples are that projections are based on future scenarios which may or may not occur, human actions in response to forecasts are undetermined, and change may occur non-linearly and faster than forecasted (Walker et al, 2004). Berkes (2007) argued that resilience is important to the discourse of vulnerability because the approach evaluates the system holistically and focuses on the ability of the system to absorb or adapt to any hazards. A resilient system must be able to deal with multiple possible impacts and have the capacity to reorganize. Recognizing uncertainty and managing for all scenarios requires forward looking and the creation of options through exploration and adoption of plausible adaptations and policies. The forward looking nature of resilience thinking relates to adaptive capacity, which is the conscious ability of social entities to forecast, predict, plan, adapt and cope.

Vincent (2004 – as quoted in Thornton et al, 2006) explains that African communities are generally well adapted to the climate variability of which they have been exposed. However, the rate of change and extreme events lie beyond their coping range. Figure 5 shows that a community's coping range for dealing with drought can increase or decrease over time. Frequency of drought can diminish the coping range. A community might be able to draw on stored resources during the first drought but if subsequent drought occurs before those resources have been replaced then the community will have a smaller coping range. Adaptive capacity and its manifestation as implemented adaptation measures are influenced by many factors. For example, access to financial resources, technology, information

and skills, kinship networks, the level of infrastructure and/or political will can all influence which strategies are implemented (Smit and Wandel, 2006; Smit and Pilifosova, 2001).

Within the water resources sector, the uptake of the Integrated Water Resources Management (IWRM) philosophy promotes building resilience and facilitates identifying vulnerabilities and potential adaptations. IWRM recognizes that water resources need to be managed holistically, taking into consideration the interconnections between users, environments, temporal and spatial scales, and in a manner that reflects the variability and uncertainty associated with water resources (Sadoff and Muller, 2009).

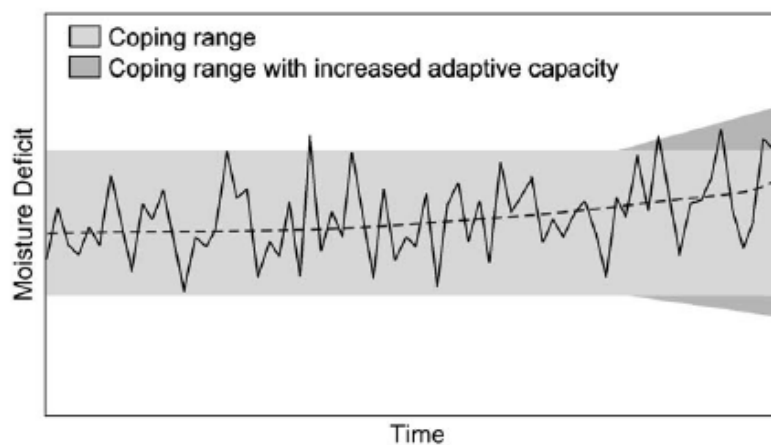


Figure 5. Coping range and extreme events (Smit and Wandel, 2006)

2.6 Integrated Water Resources Management

The following statement from the Chair of UN-Water, Pasquale Steduto and the Chief Technical Advisor for UN-Water, Johan Kuylensstierna (n.d) addresses the need for appropriate water management in order to deal with climate change:

Water frequently functions as the link between the climate system and human society. Most natural catastrophes are water related – floods, droughts are the most obvious examples. If we manage water, we can, to a large extent, manage climate variability and thus also better prepare for climate change. Strategies related to climate change adaptations must, therefore, increasingly focus on water resources management

The African Water vision (2003) also recognizes the need stating “that the threats cannot be successfully addressed by adherence to business as usual in water resources management at national and regional levels”.

Pre-IWRM (pre-1990’s) water management was dominated by development of infrastructure and the perception that nature could and should be controlled (Arab Water Council, 2009). This supply-driven approach was top-down and sectoral (Allan, 2003; Savenije and Van der Zaag, 2008).

Savenije and Van der Zaag (2008) note that “the approach was typically sub-sectoral, mostly in relation to water supply, sanitation, irrigation and energy. Engineers would predict the demand for water and the need for projects and subsequently provide in those needs”. As concerns and needs of ecosystems were ignored, water resources were frequently overexploited, resulting in unacceptable outcomes. The recognition of environmental concerns and the social, ecological and economic constraints within the water sector gradually gained international attention. The culmination of the increased awareness resulted in the call for IWRM and the formulation of Dublin principles. The Dublin principles were formulated in a consultative process at the International Conference on Water and the Environment in Dublin, 1992. The principles act as the foundation for promoting water sector reform. The four Dublin principles are (GWP, 2000):

- Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment
- Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels
- Women play a central role in the provision, management and safeguarding of water
- Water has an economic value in all its competing uses and should be recognized as an economic good

IWRM is not meant to provide a concrete blue-print of how water resources should be managed, in fact at its core IWRM recognizes that there cannot be a one-size fits all remedy. Instead it should be viewed as a philosophy, offering a guiding conceptual framework (Cap-Net, 2008). The philosophy departs from the traditional approach by calling for a holistic view of the system, integrating all water

(focusing on the river basin instead of a single water course), land and water, spatial and temporal scales, sectors, water uses (including ecosystems) and all stakeholders.

2.6.1 ‘Integration’ in IWRM

Effective management requires integrating various factors that have previously been considered in isolation.

Water Resources

All water resources need to be considered by focusing on the entire hydrological cycle. IWRM promotes using the river basin as the boundary of the system (Cap-Net, 2008; Heathcote, 1998; Schreier 2003, 2004; UNEP, 2006). The river basin approach uses an area of land bound by topographic features that drains water to a shared destination. This approach moves beyond anthropocentric political boundaries and instead focuses on a natural unit, that collects precipitation, filters and stores water and connects the flows of water, sediment, nutrients, energy between air, soil, vegetation and water bodies. Savenije and Van der Zaag (2008) describe a holistic view of water resources as “including stocks and flows, as well as water quantity and water quality” and “distinguishing for example, rainfall, soil moisture, water in rivers, lakes and aquifers, in wetlands and estuaries, considering also return flows”. The impact of land use and vegetation cover on the quality and distribution of water is facilitated by taking into account the entire basin. This integration of land and water has also promoted the conception of ‘green water’ in addition to the traditional focus on ‘blue water’. ‘Blue water’ is the water available in rivers, lakes and aquifers, whereas ‘green water’ is the water flow that supports plant production in forests, grasslands, rainfed agriculture and wetlands (Moberg et al, 2005). The GWP (2000) explains that “terrestrial ecosystems are dependent on ‘green water’, while aquatic ecosystems are ‘blue water’ dependent”.

Spatial Scales

Water resources are not evenly distributed, nor has water related infrastructure been equitably developed, as a result interests, accessibility and use of water resources varies throughout a landscape. The system approach of IWRM takes into account these discrepancies. For example, managers are asked to recognize that upstream users withdrawing large amounts of water are limiting the accessibility to water of downstream users.

Temporal Scales

Temporal variation and patterns are inherent in water resources and in demands for water resources. Several factors can cause temporal distribution of water such as seasons, snow melt, ENSO events and climate change. Human activities and ecosystem needs fluctuate throughout the year, for example agriculture water requirements depend on cropping patterns. Management needs to incorporate expected declines or increases in availability and adjust measures appropriately.

Water Uses and Values

There are many different uses of water which are either consumptive (households, industries, agricultures, ecosystem etc) or non-consumptive (hydropower, fisheries, navigation, recreation etc). The first Dublin principle states that water is finite and vulnerable therefore the potential uses are competing for access to the limited resources. Water managers need to integrate competing and often conflicting objectives and make tradeoffs based on full information, transparency and with recognition of the true value of water (GWP, 2000; Medema and Jeffrey, 2005; Savenije and Van der Zaag, 2008). In contrast to sectoral approaches which led to fragmented and uncoordinated development of the resources, IWRM promotes a cross-sectoral approach (Figure 6). It calls for water resources policy and management to consult and integrate the views of all relevant line ministries. Coordinating water allocation for the basin necessitates the integration of the various sectors (GWP, 2000). Decisions of provision are based on value assumptions of which interests and uses are more important than others.

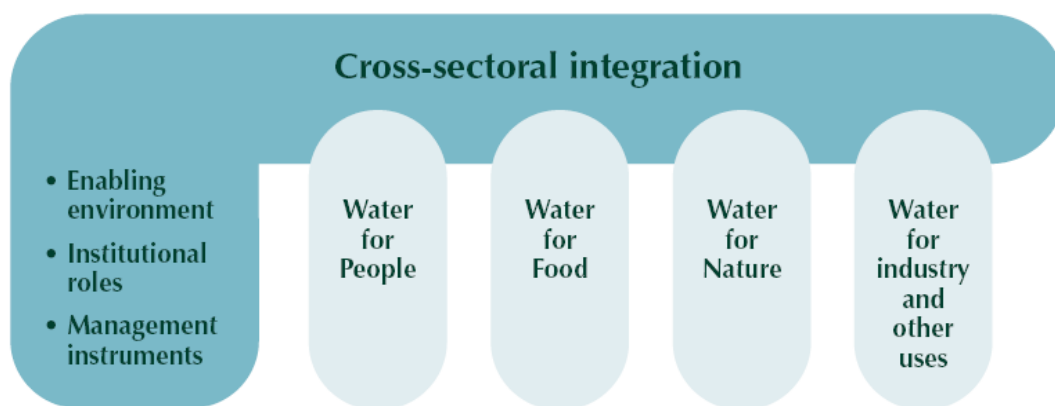


Figure 6. IWRM and its relation to sub-sectors (Source: GWP, 2000)

Stakeholders

While integration of all sectors is necessary to determine coordinated allocation, integration of all stakeholders is necessary to determine the value of potential uses and achieve consensus.

Encouraging participation, which can balance top-down and bottom-up approaches, may require awareness raising, capacity building, education and the provision of economic resources. IWRM calls for real participation, which in contrast to consultation, requires that stakeholders at all levels have an impact on decisions and are provided with the tools necessary to be informed (GWP, 2000).

Integration facilitates better and more effective regulation, more successful, culturally and socially appropriate projects. In addition, informed local users are more likely to provide and enforce environmental protection. Sadoff and Muller (2009) state that “good management practices that are developed in user communities are more likely to be sustainable than rules imposed from outside by formal organisations”.

2.6.2 IWRM Framework

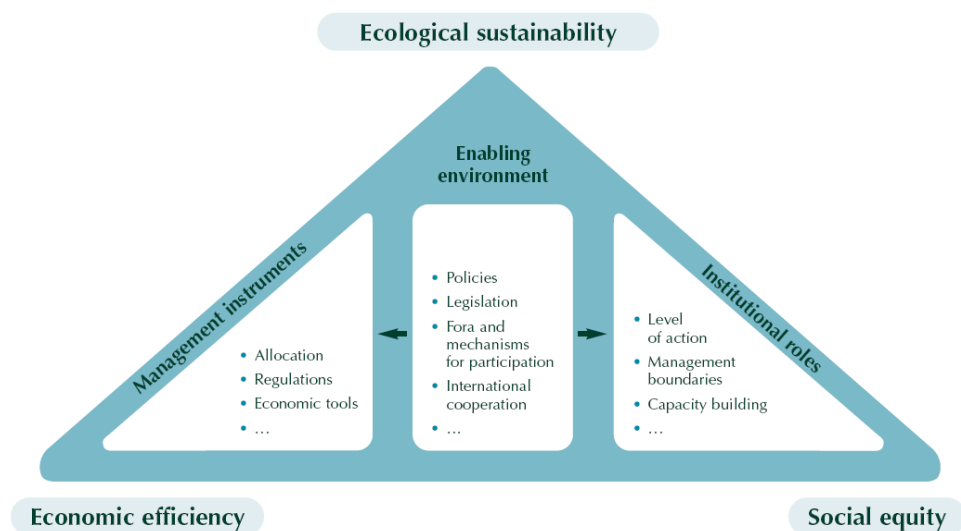


Figure 7. IWRM conceptual framework (Source: GWP, 2000)

Figure 7 schematically represent the IWRM framework composed of a set of overriding criteria and set of three complementary elements needed for effective management.

The overriding criteria provide guidance on the need to balance social, economic and ecological water requirements. IWRM philosophy requires managers to take into account the three Es:

Equity – The basic human need and right (as we cannot survive without it) to have access to water of adequate quantity and quality for the sustenance of human well-being. Savenije and Van der Zaag (2008) express that water is often conceived of as a public good, but the fact that water is a finite resources and is fundamental for survival necessitates society to manage, defend and equitably distribute the resource amongst the users.

Ecological Integrity – This principle respects the life-supporting role of ecosystem and upholds the need to manage water resources so as not to undermine natural environments. Also incorporated in this principle is the acknowledgement that ecosystems regenerate freshwater (Savenije and Van der Zaag, 2008).

Efficiency – Water is a finite and vulnerable resource that needs to be managed efficiently.

Efficiency promotes demand side management measures such as the promotion of conservation; supply side management also needs to be managed more efficiently such as ensuring that there are no leaks in the system.

As a framework for IWRM, the GWP (2000) describes three elements within the water sector that need to be developed concurrently. The first is the creation of an enabling environment through appropriate policies, strategies and national regulations. An IWRM arena requires mechanisms for stakeholder participation, which also speaks to the second element of formulating institutional roles. Determining appropriate levels of actions and management boundaries for all involved institutions will enable the proper implementation of policies and regulations. The third element addresses the various and wide array of management instruments required by institutions based on policies. Instruments will be needed to enable allocation, regulation, monitoring and enforcement. IWRM recognizes that both ‘hard’ or structural and ‘soft’ or institutional measures will need to be implemented.

2.7 Summary

The deliverance of water resource management’s core objectives, namely to mitigate the impacts of extreme events and to satisfy competing demands including ensuring continued equitable access for human well-being, for livelihoods and to maintain environmental integrity, are increasingly challenged by climate variability and change and other driving variables. These challenges are associated with large levels of uncertainty and therefore necessitate a focus of building social-ecological systems that are able to cope with, adapt to and shape change.

The GWP (n.d – as quoted in Cap-Net, n.d) states that “the best way for countries to build capacity to adapt to climate change is to improve their ability to cope with today’s climate variability”.

Identifying system vulnerabilities including, exposure to climatic hazards (present and future) or

culmination of other driving variables (i.e. population growth), the inherent system sensitivities, and capacities for adapting, illustrate the relationships and web of connections between the component parts of a systems and point to possible routes of interventions.

In rural Africa, water is inherently connected to all facets of life and development, and the availability and accessibility of which has been shown to not only be affected by environmental factors, such as climate, but also be a result of unbalanced power relations, poverty and related inequalities (Falkenmark et al, 2007). In order to manage the resource more holistically and effectively, the African Water Vision 2025 and the IPCC Working group II (UNWAfrica, 2003) advocate for an IWRM approach.

IWRM has been regarded as a necessary adaptation to climate change, as a tool used to identify adaptations and as essential to building resilience (Bates et al, 2008; Moberg and Galaz, 2005; Sadoff and Muller, 2009). Climate change will simultaneously affect multiple sectors, necessitating coordination. IWRM is thus viewed as an adaptation to climate change because it promotes sector integration and ensures that activities in one sector do not undermine another. The IWRM philosophy takes a holistic approach to managing a social-ecological system which enables viewing all dimensions of vulnerability. In addition, IWRM's adherence to its core criteria or three E's and 'real' participation of all stakeholder, facilitates lessening power imbalances and inequalities in allocation. Building more effective institutions and investing in a variety of 'hard' and 'soft' measures to reduce system vulnerabilities are also forms of climate change adaptation. As IWRM promotes options for management that increase coping capacity, builds institutions that are capable of adapting and formulates relationships that facilitate re-organize in the face of disturbances and change it builds resilience.

3. Research and case study background

On January 9th, 2009, one month after the commencement of this study, the government of Kenya declared a national emergency (Associated Press, 2009). The failed *short* rains had put more than 10 million people at risk of going hungry. During the next four months, the situation worsened. The communities of *Ukambani* and the site of the study struggled as water sources dried up, fields lay bare and the few germinated crops withered. Finding and accessing food and water became the priority, halting and often reverting development activities. As the onset of the *long* rains in April approached, anxieties grew and tradeoffs were made regarding decisions of whether to plant and when to plant any remaining seeds. Unfortunately, like the previous wet seasons, the rains failed again. This highlighted the reality that water scarcity is not a future threat of climate change but is having a very real, present and devastating impact on communities in ASALs.

The lack of perennial rivers, the combination of short intensive rainfall events, excessive runoff and high potential evaporation in these areas leave little time for water to recharge the groundwater. Adaptation strategies, therefore, need to focus on water supply infrastructure that increases storage and retention time of rainwater and allows the water to infiltrate into the soil, to raise the water table and to be stored for use throughout the dry season (Mutiso, n.d.). As improving water security in Africa's rural areas necessitates low cost, low maintenance solutions that involve the local community, the construction of sand dams is increasing in popularity (Mutiso, n.d.). Sand dams represent a storage system strategy that is cost effective, amenable to participatory development and builds resilience by facilitating livelihood diversification, ecological restoration, and community organization (Lobe, 2008).

3.1 Water in Sand



Figure 8. Typical sand storage dam (Borst & de Haas, 2006)

A sand dam by definition is an impervious barrier built across an ephemeral stream⁷. Over time coarse sand, carried by flow during the raining season, accumulates against the upstream side of the wall, filling the reservoir with sand and greatly enhancing the riverbed storage capacity. Coarse textured sand has large voids between the sand particles which are filled with water during flash-flood events. The amount of water that can be held by a given volume of coarse textured sand is 35 percent of the volume (Nissen-Petersen, 2006). In other words, for every cubic meter of saturated sand 350 litres of water can be extracted.

Typically in ASALs during the rainy season, rivers have a surface flow for only short periods (only a few hours to a few days) after intense rainfall events (Mutiso, n.d). The flow appears as a flash-flood (Nissen-Petersen, 2006). During the dry seasons, local people access the remaining base flow by digging deep scoopholes in the riverbed (Figure 9). However, generally even the riverbed's aquifer will dry up before the next rainy season (Mutiso, n.d). A sand dam's foundation is built on an impermeable base layer in order to completely block the base flow and the associated loss of water downstream. Over the years as the dam matures and the sand brought down with each runoff event

⁷ Ephemeral streams are seasonal water courses that collect and transport catchment runoff to rivers.

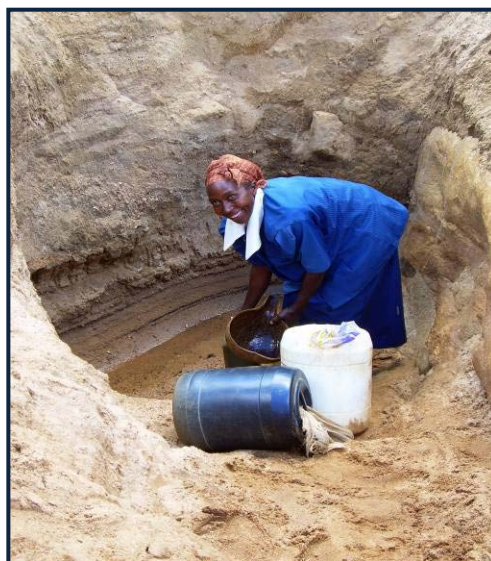
accumulates behind the dam the potential amount of groundwater that can be held by the riverbed aquifer increases (Figure 10) and water remains throughout the entire dry season.

The use of sub-surface storage as a water harvesting technique is not new, in fact they have been used since 9000 BC (Oweis, 2001 – as quoted in Quilis et al, 2009). On the island of Sardinia for example, dams that blocked the flow of groundwater were found in Roman time (Nilsson, 1998 as quoted in Quilis et al, 2009). In addition, sand storage dams have been used in the Middle East for thousands of years, in India for centuries and in Southwestern United States and northern Mexico since the 1800s (Quilis et al, 2009; Nissen-Petersen, 2006).

In Kenya, the first sand dam is believed to be constructed by an ex-WWI soldier, Mr. Nzamba. He constructed the sand dam in 1928 in Mathima location, Mutomo division, Kitui District (Isika et al, n.d.a). The colonial government built more sand dams as part of the African Land Development Board project which took place in Ukambani between the years 1954 and 1963 (Nissen-Petersen, 2006).



Figure 9. Women in Sakai sublocation traditionally collecting water from scoopholes in ephemeral streams



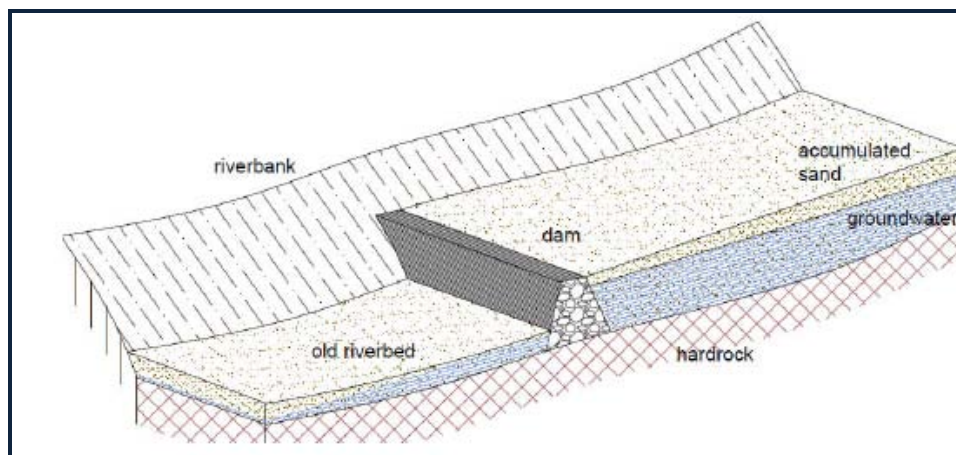


Figure 10. Schematic cross section of a typical sand dam (Borst & de Haas, 2006)

While the ultimate function of a sand dam is to increase the amount of available water, there are other added advantages, such as the sand acts to protect the water from the high evaporation rates. Water that is 60 cm or more below the surface of the sand experiences virtually zero evaporation (Nissen-Petersen, 2006). The stored water raises the groundwater table of the surrounding areas, positively affecting the environment. Higher water tables improve the amount of vegetation along the banks and can permit farmers to grow vegetables adjacent to the sand dam. The sand also acts as natural filtration system, disinfecting the water people will use for domestic purposes (RAIN Foundation and Acacia Water, 2007). Contamination of the water from livestock and other animals is reduced as the water is protected by sand layers. In contrast to surface water dams, sand dams are unsuitable breeding ground for mosquitoes and other vector insect.

3.2 Country background

Located in East Africa on the coast of the Indian Ocean, Kenya borders Tanzania, Uganda, Sudan, Ethiopia and Somalia (Figure 11). Administratively, Kenya is divided into 8 provinces, which are separated into 254 districts⁸. The districts, which are the charge of a District Commissioner (DC), are

⁸ There has been a large addition in the number of districts, which has risen from 70 in September 2006 (Few et al, 2006). The increase is “meant to serve as a means of bringing government services closer to the people...” and serves as “one of the ways of tackling growing insecurity in the country” (Methenge, 2009). 70 of the additional new district headquarters that need to be built are expected to cost the government Sh 2.1 billion (Methenge, 2009).

then subdivided into divisions, headed by a divisional officer. Divisions are further divided into locations led by a government appointed chief, and sub-locations with an assistant chief. The smallest administrative unit is the village, which is usually headed by a village elder.

Kenya's landscapes are greatly varied with glaciated mountains, alpine highlands, coastal environments, savannahs, deserts and semi-deserts. The climate ranges from tropical along the coast to arid in the interior (UNEP, 2006). Only 20 percent of Kenya's 582 646 km² landmass is classified as arable, while the remaining 80 percent is ASALs. The country experiences bimodal rainfall with *long rains* from March to May and *short rains* from October to December (coinciding with the passing of the Inter-Tropical Convergence Zone)⁹. Rainfall patterns are highly variable both temporally (from season to season and year to year) and spatially, with annual rainfall from 200 mm in the ASALs to 1,800 in the high elevation Western region. Weather related hazards also play a common theme in Kenya's climate (Few et al, 2006). When the rains are late the country experiences agricultural drought¹⁰; sudden, intense rains frequently cause flooding; and the increasingly common failure of rains result in dried water sources and famines. Since the 1990's Kenya has declared six national disasters in 1991/92/93, 1996/97, 1999/2000/01, 2005/2006 and 2008/2009 due to droughts and 1997/98 related to El-Niño floods (UNDP, n.d; Mbuvi, 2006).

Kenya's population of over 38.5 million is increasingly vulnerable to climate related hazards. A high population growth rate, high levels of deforestation and unemployment, inequitable land ownership, and dependence on limited natural resources all influence the social and economic realities for many Kenyan's caught in cycles of poverty (Few et al, 2006). More than 56 percent of the population is living below the poverty line (GoK, 2005). Poor economic performance resulted in an additional 2.7 million people living on less than US \$ 35 per month for urban dwellers and US \$ 16 per month for

⁹ The short and long rains refer to the length of the individual rainfall events (Lasage et al, 2008)

¹⁰ Agricultural drought is defined as periods where there isn't enough soil moisture to meet the needs of a particular crop at a particular time (Few et al, 2006).



Figure 11. Location of Kenya
(Source: Office of Public Communications,
Government of Kenya)
<<http://www.communication.go.ke/media.asp?id=597>>

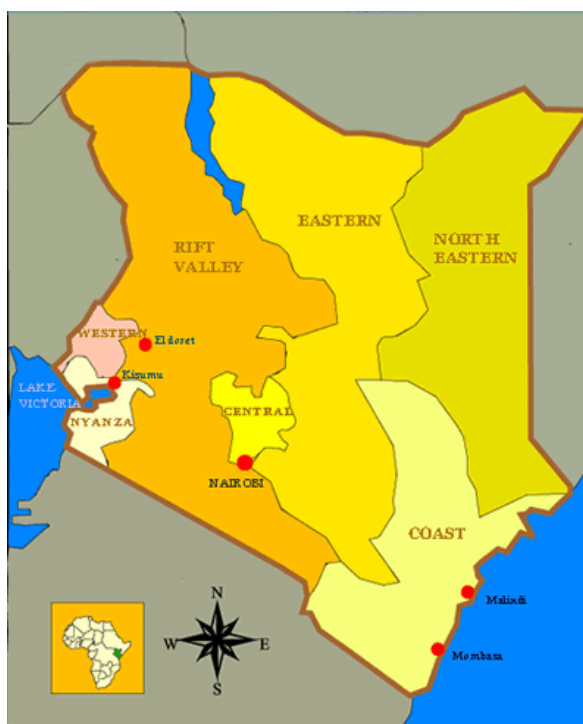


Figure 12. Kenya's Provinces
(Source: <http://www.kenya-advisor.com/images/kenya-map-provinces.jpg>)

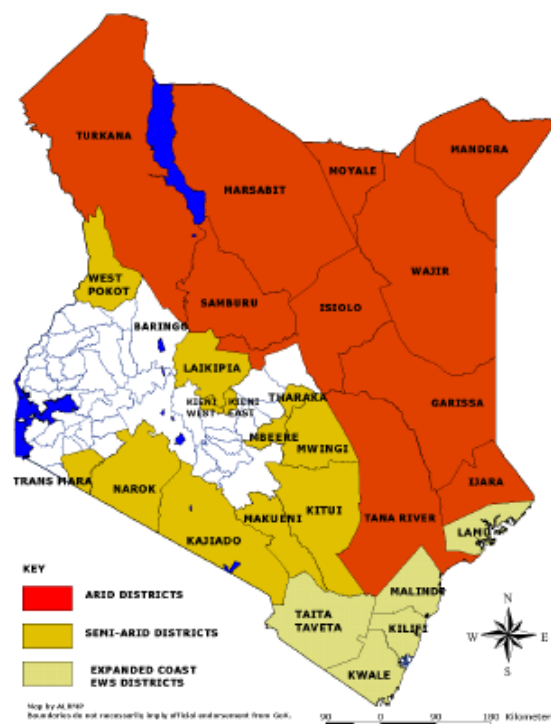


Figure 13. Location of Makueni and Kitui Districts
within Kenya's Arid and Semi-arid Lands
(Source: ALRMP)

rural inhabitants from 1997 to 2001 (GoK, 2005; UNEP, 2006). Three quarters of Kenya's poor live in rural areas, which is home to 67 percent of the population and poverty levels are increasing steadily especially in the country's ASALs.

Over 2 million Kenyans are unemployed (GoK, 2005). Agriculture is the most important sector to the economy, accounting for 26 percent of the country's GDP and employing 80 percent of the population (UNEP, 2006). The majority of Kenya's poor rely on subsistence agriculture, pastoralism, and informal employment in urban centres for a livelihood. Agriculture predominately relies on rainfed production, which when combined with Kenya's erratic rainfall patterns and growing water and food insecurity, results in frequent national emergencies (UNEP, 2006; Few et al, 2006). In 2004, the population of food insecure was 15 million which rose from 1973 levels of 7.3 million (UNEP, 2006). Food insecurity and malnutrition rates are highest in ASALs. These areas, where 2 – 5 million can become dependent on food aid during major events, are highly vulnerable (Few et al, 2006).

Kenya is considered a water scarce country with surface water covering only 2 percent of the landmass and an annual availability of 647 m³ of renewable fresh water per capita (UN-Water, 2005; UNEP, 2006). By 2020 this availability is expected to drop to 359 m³ per capita due to population growth (UNEP, 2006). While 68 percent of the urban population has access to safe water, only 49 percent have access in rural settlements (UNEP, 2006). In terms of energy consumption, fuelwood and charcoal account for 66 percent and only 9 percent is produced by hydropower.

The Eastern Province, where this study was conducted, is Kenya's second largest province and is primarily inhabited by Ameru and Akamba communities. It borders Ethiopia to the North, North Eastern and Coastal Provinces to the East, and Central and Rift Valley Provinces to the West (Figure 12). The province is composed of eleven districts, of which four (Machakos, Makueni, Kitui,

Mwingi) make up the area known as *Ukambani*, or the traditional homeland of the Akamba¹¹. The principal focus of this research is on the *Ukambani* region, specifically the arid and semi-arid districts of Makueni and Kitui¹² (Figure 13). The districts, respectively, cover an area of 7,956 km² and 20,000 km² and are home to approximately 839,155 and 555,000 people (Ministry of Planning and National Development, 2002; Lasage et al, 2008). Eastern province is home to some of the poorest areas in Kenya, and has more than 58 percent of its population living below the poverty line. Significantly higher than the province's average, Makueni and Kitui Districts have 70 and 69 percent of their populations living in poverty. In addition in both districts the majority of the population live in rural areas (90 and 82 percent, respectively), which have a higher percentage of people living below the poverty line than in urban areas. Rural dwellers are dependent on small-scale farming and pastoralism for a livelihood, which combined with low and erratic rainfall creates a population vulnerable to water scarcity (Few et al, 2006; Ministry of Planning and National Development, 2002).

3.3 Case study background

The research question and objectives were investigated through a case study approach. As this exploratory study was informed by constructivist epistemology, the case study approach allowed the researcher to describe, understand and explain an outcome in its particular setting; accepting that each individual and community¹³ have their own context and interactions impacting their level of motivation. Thus, while the overall goal of the study is to inform the evolution of future projects, findings will not necessarily transfer as context and experiences differ.

¹¹ Eastern province actually has 26 districts which were created when the main eleven districts were subdivided during the 2007 elections. The *Ukambani* region is also composed of more than four districts as the four mentioned were subdivided in 2007.

¹² Makueni and Kitui District were subdivided during the 2007 elections. As a result the Makueni sand dam projects are now located in Mbooni District and several of the Kitui sand dam projects are located in Mutomo District. However, because both project documentation and the institutions responsible for these projects remained in Makueni and Kitui Districts, respectively, this research will refer to the projects as located in their original Districts.

¹³ The definition of a community varies widely in the literature. It is commonly denoted as a group of people sharing a common interest. For this study the community is being defined by political boundaries designed by the Government of Kenya. For example the village which is demarcated by the government will be considered a community.

The selection of the case study and case study locations resulted from multiple factors including previous experience working in Sub-Saharan Africa, a summer internship with the International Development Research Centre's Climate Change Adaptation in Africa (CCAA) program and the generosity of several Kenyan institutions agreeing to host the research. As a research assistant on a food security project in rural South Africa, the advantage of having sustainable access to water was first highlighted. It was apparent that farmers who were able to adopt water conservation and harvesting methods were less vulnerable to dry periods and low yields. Further exposure to the plight of African communities and the compounding impacts of present and future climate change were underlined during my internship with the CCAA team. I was pursuing a research project centering on how rural African communities are going to cope with ongoing environmental change, while securing water for livelihoods, health and wellbeing. As sand dams represent an innovative but underutilized adaptation strategy, I decided to focus on programmes implementing these development projects (Falkenmark et al, 2001).

During a 5 month period, five Kenyan sand dams projects, completed by two different institutions and from different rural areas in two of Kenya's semi-arid districts were evaluated (Appendix A – summary chart of case studies). Four of the five sand dams had already been constructed and have been operating for various length of time. The fifth sand dam was still in the construction phase of the project. The two institutions were selected as they were addressing water scarcity through the construction of sand dams. From each institution three sand dams were selected as case studies, however, due to time constraints only two were evaluated from one institution. The two semi-arid districts represented areas that lacked reliable potable water sources and experienced high levels of food insecurity which created a vulnerability that would benefit from the effective implementation of adaptation strategies. In fact both areas have frequent emergencies due to crop failures and food shortages.

The two institutions were:

A. The Arid Lands Resource Management Project (ALRMP) and the Centre for Science Technology Innovations implementing the ‘Increasing community resilience to drought in Makueni district’ (Resilience) pilot project.

B. Sahelian Solutions (SASOL), a Kenyan Non-Governmental Organization (NGO) based in Kitui District, Kenya.

The two implementing institutions differed in many aspects. One was a pilot project, whereas the other had a long term presence in Kitui District. One was based from a government office while the other was an NGO and the projects both had different initial focuses. The Resilience pilot project sought to address community vulnerability to drought through prioritizing several goals simultaneously. While sand dams were a priority for improving water security, it formed only one of the main goals of the project. In contrast SASOL, who overall also seeks to reduce vulnerability to drought, does so through using water as a platform. The belief is that the sand dam projects provide the necessary access to water for other development activities and the organization of the community resulting from the building the sand dam creates the unity to accomplish other initiatives (Mutiso and Mutiso, n.d.). The differences between the two implementing organizations provided an opportunity to have a more well-rounded examination of the impacts of varying approaches.

3.3.1 The ‘Increasing Community Resilience to Drought in Makueni District’ Adaptation Project, Makueni District, Kenya

The regional project “Integrating Vulnerability and Adaptation to Climate Change into Sustainable Development Policy Planning and Implementation in Southern and Eastern Africa” was initiated by the United Nations Environment Program (UNEP) in 2006. Through pilot projects undertaken in Kenya, Mozambique and Rwanda, that focused on priority areas such as water and agriculture, the regional project expected to build the capacity of each country to generate and use climate

information and to implement adaptation strategies in the field as well as to integrate climate knowledge into policies and plans.

In Kenya, the 3 year and US \$ 300,000 ‘Increasing community resilience to drought in Makueni District’ pilot project was carried out by the Centre for Science and Technology Innovations (CSTI) and implemented locally by the Arid Lands Resource Management Project (ALRMP) (Opondo, n.d.). The project leads from the CSTI consisted of researchers from multiple disciplines, who directed the work carried out by the ALRMP. The CSTI is a UNESCO associated centre based at the Kenya National Academy of Sciences. The institutions mandate is to “improve life through science, technology and innovation”. The ALRMP is a community-based drought management program initiated as a Special Government Programme in 1996. The second phase of the ALRMP, which increased the number of arid and semi-arid districts covered to 28, began in 2003. The project monitors the local livelihoods to provide early warnings of emergencies and long term goals of community development to reduce poverty and vulnerability.

The sub-location Sakai in Makueni district was selected for the pilot project in Kenya as Makueni district had experienced devastating impacts from droughts; had a high concentration of people which maximized project impact potential; and had existing and ongoing ties with ALRMP. The sub-location experienced an average drought related risk and given the short time-line (3 yrs) and limited funds, it was believed that the greatest intervention and impact could be realized in this area. Sakai is situated 20 km from one of Makueni’s major centres, Wote¹⁴. It is home to approximately 750 households and a population of 4,800 (Resilience project, n.d.). Five villages (Muiu; Kathamba; Kiteani; Linga; Nthongoni) combine to cover an area of 24.5 km² (Figure 14).

¹⁴ Wote is the capital Makueni District and the location of district headquarters and the ALRMP offices. This market has an urban population of approximately 5500 and connects via a (relatively) paved highway to Nairobi, Machakos and Mombassa.

The goals of the pilot project were to increase household food security through increased livelihood resilience and reduced vulnerability to drought; to reduce poverty through improved livelihoods; and to facilitate integration of climate change and adaptation into policy development and planning. After review existing literature on Makueni district and collecting baseline data, points of intervention, such as agricultural practices, self-help groups and improving access to water, were identified. The CSTI and ALRMP teams initiated the pilot project in coordination with the assistant chief and the village elders by calling a *baraza*¹⁵. At this meeting, they explained to the community the project and asked each household to complete a ranking questionnaire. From these questionnaires the team selected 40 farmers¹⁶ to house demonstration gardens. The 40 farmers were trained on appropriate agricultural practices, animal husbandry, seed bulking, pest control, and post harvest storage. The pilot project also emphasized farmer-to-farmer training and sharing of seeds, resulting in 120 farmers to date being trained in proper practices.

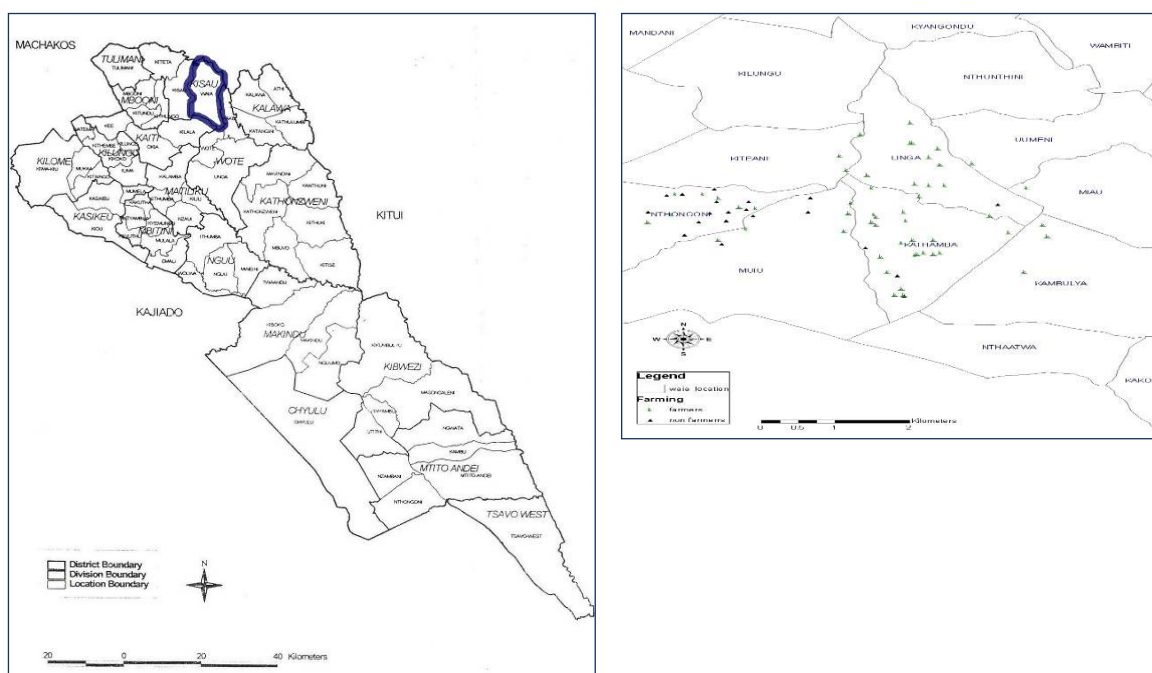


Figure 14. Map of Makueni District with Kisau Division highlighted (left – Source: Ministry of Planning and National Development, 2002). **Map of Sakai sublocation and villages** (Source: Mutua, n.d.)

¹⁵ Community meeting.

¹⁶ The 40 farmers were selected fairly evenly between the five villages in Sakai

As a key impact of drought, identified by the communities, was loss of crops due to unpredictable rainfall, the pilot project also endeavoured to provide more user friendly climate information. The team received forecasts from the Kenya Meteorological Department (KMD) and ‘downscaled’ the national weather forecasts into local and agrometeorological terms. This information, such as types of crops to plant and when to plant, was then disseminated in local languages over the radio, newspapers and in brochures handed out at community meetings (Appendix B).

At the same meeting the team explained their goals of building sand dams, shallow wells and drip irrigation systems and to help local self-help groups access activities that would diversify their income. The five villages were asked to identify locations they deemed as appropriate for a sand dam, which were then assessed for feasibility by a technical team (ALRMP, 2007). Five locations were initially selected, but due to funding constraints only three sand dams would be constructed by the pilot project (Figure 9). Two of these have been built and the community has prepared the site for a third.

In terms of policy linkages the pilot project engaged with district- and national-level policy makers and communicated project lessons. Data collected and preliminary lessons learned influenced the National Disaster Management Strategy and the Sustainable Development of Arid and Semi-Arid Lands policy document.

Location of case studies covering the ‘Resilience’ project’s sand dams

This research focused on the three communities where the pilot project decided to build sand dams (Figure 15). The first sand dam constructed, Kwa Dison, is located in **Muiu** village, along Lumu Stream (GoK, n.d.). This sand dam is functioning quite well but is still immature and the water collected is only used for watering livestock. In addition, the Kwa Dison sand dam committee is inactive. The second one, Kwa Mutingu, is located in **Nthongoni** village, along Mutingu stream. Kwa Mutingu was not completed and poorly constructed. The water that has collected is only fit for

livestock. The installation of a pipe for drawing water was never completed. The dam has severe problems with siltation and the structure is leaking. The sand dam committee for Kwa Mutingu is also inactive. The construction of the third sand dam, Kwa Ndeto, in **Kathamba** village, along Mutomo stream, has not begun. The sand dam committee is active and has prepared the area three times, as the cement did not arrive in time after the first and second attempts at digging the trench resulting in it being washed away by the rains.



Figure 15. Makueni case study sand dams (from left to right: Kwa Dison, Kwa Mutingu, and Kwa Ndeto)

3.3.2 SASOL, Kitui District, Kenya

Sahelian Solutions or SASOL Foundation is a local Kenyan NGO that has been operating in ASALs since 1990. The NGO focuses on dealing with drought mitigation and capacity building and seeks to address household and production water scarcity through sand dam technology. One of their main objectives came as a result of witnessing women in Kitui District spending one hour walking from the Kiindu River to the Nzeeu River and one hour back in search of water (Borst and de Haas, 2006). The NGOs goal thus is to shorten the distances to water sources to below two kilometres and make water available for alternative production systems (Isika et al, n.d.a). To date SASOL has built over 500 sand dams in Kitui District, Kenya, which is the highest concentration of sand dams around the world.

SASOL debuted as a typical Kenyan NGO dealing with drought food distribution in Kenya and Somalia and encouraging the production of cash crops. Their later transition to supporting schools, first by sponsoring children who could not afford fees and subsequently through feeding components, led SASOL to identify water constraints as the key limiting factor in reducing poverty in Kenya's ASALs. At first SASOL concentrated on wells but in 1996 they constructed their first sand dams. Today, they operate under three principles. The first principle outlines their belief that although the

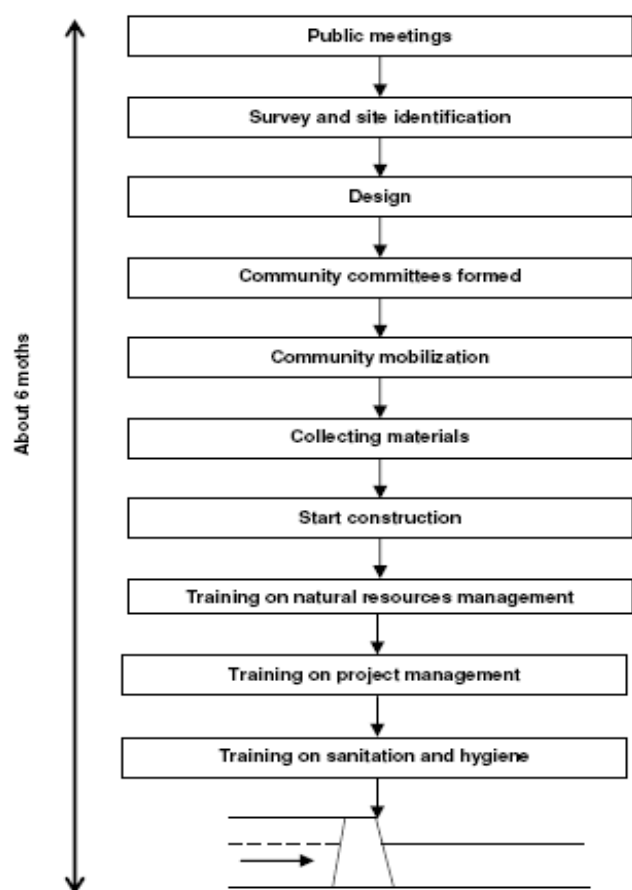


Figure 16. SASOL design process (Ersten et al, 2005)

technology is simple, it has enormous social organization potential. The second principle is to focus on 'green' water¹⁷ instead of the predominant focus on 'blue' water. Sand dams act to enhance the system as opposed to wells which are purely extractive. The third principle expresses the need for the communities to be involved in the whole process. SASOL provides the community with the material and knowledge but requires that the demand, drive and labour all come from the community.

With SASOL's high concentration of sand

dams in Kitui district, the team has seen many benefits. Over 120,000 people have improved

access to water (Borst and de Haas, 2006). SASOL states that "households on land adjacent to the regenerated rivers are now earning more than 100,000 Ksh from bucket irrigation during the three dry

¹⁷ Green water is the water used by the terrestrial ecosystem such as through plants whereas blue water is the water available in river, lakes and aquifers.

months of August, September and October”. SASOL’s approach to development coined as the ‘sand dam development paradigm’ follows an eight step process that occurs over approximately 6 months (Figure 16).

Location of case studies covering SASOL’s sand dam projects

Two randomly selected SASOL sand dam projects were visited. The projects were the Musingu sand dam along the Muvuko River, in Mutha division, Kanziku location, **Keutunda** sub-location and Kwa Ndunda sand dam along the Kiindu River, Kitui Central division, Mulango location, Kyangunga sublocation, **Kitunda** village (Figure 17, 18).

The second location is approximately 15 km from Kitui town, which is the district’s capital, while the first is located approximately 25 km from Mutomo. Both sand dams in Kitui District were functioning well, while the sand dam committees have disbanded.

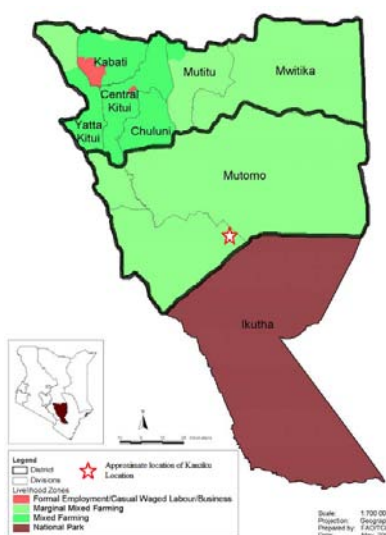


Figure 17. Map of Kitui District. Musingu sand dam is located in Kanziku location indicated on the map by the red star. Kwa Ndunda sand dam is located in Central Kitui on the outskirts of the formal employment zone (Source: GoK)



Figure 18. Kitui District sand dams (top to bottom: Kwa Ndunda and Musingu dams)

4. Methodology

“Human behaviour, unlike that of physical objects, cannot be understood without reference to the meanings and purposes attached by human actors to their activities”
(Guba and Lincoln, 1994)

Several methods were used in combination to ensure reliability and validity (Lincoln and Guba, 1994). The use of multiple methods in qualitative research provides a means of situating accounts and revealing multiple constructed realities (Seale, 1999).

The collection of secondary information began in Canada with a review of relevant literature related to climate change, water resources management and adaptation strategies in Sub-Saharan and in particular in ASALs. This review was important to gain a more comprehensive understanding of the issues and research initiatives taking place in the study area. Project and related non-project documents that could be accessed from Canada were also reviewed. Several project related documents for the Makueni pilot project could be accessed from the projects website: www.csti.or.ke, as well as from the ALRMP website: www.aridland.go.ke.



Figure 19. Self-help group workshop, Sakai Sublocation - December 16-17, 2008

The first 6 weeks in Kenya were used to become familiar with the area, finalized research methodologies and time lines with project proponents and collect any secondary data that was unavailable in Canada. I was also fortunate to attend a two day workshop with the self-help groups being funded through the Resilience project in Makueni (Figure 19). This was my first opportunity to speak with community members from one of the study site locations. This short but invaluable interaction provided insights into the project activities, potential expectations, and a glimpse into the community.

Throughout the duration of the fieldwork other secondary sources of information were collected from the numerous institutions and organization visited, these included brochures, program materials and photographs of various posters. In addition as a means of situating community context within the larger country and political situation, articles from several Kenyan newspapers were collected as often as possible.

Primary data was collected through (1) 92 household questionnaires combined with informal, unstructured interviews; (2) 21 formal semi-structured, open-ended interviews with project leaders, community development workers, local and district administration, farmers and community groups; (3) 5 focus group discussions; and (4) participant observation.

All the data collected was recorded in a notebook, and where appropriate and participants granted permission a tape recorder was used. In many cases a tape recorder was not fitting, as the use may have changed the dynamics of the interview from an informal discussion between colleagues, to a formal interview between researcher and community member. In addition, there were times when the participants felt uncomfortable. Both occasions may have resulted in less candid responses had a tape recorder been used. In addition, many interviews were conducted outside, in restaurants, and in-transit, where the technology would not have recorded adequately.

4.1 Household questionnaires

The use and design of the household questionnaires (Appendix C) had several intentions. Perhaps the most important was the use of the questionnaire as a means of introducing myself and building a rapport with the community. I was able to explain the reason for my stay and develop a familiarity with the members. Subsequent to the completion of the questionnaires individuals would greet and approach me with thoughts regarding research, suggestions of people and places to see, while others were simply welcoming. All interactions were invaluable in understanding and embodying the context of the village, as well as building trust between myself and the community members. It was through afternoons spent in the market being accepted into conversations where I learnt the most about the struggles, hopes and dynamics of the community.

As the other research methods concentrated on key informants and the sand dam committees, the questionnaires provided a means of giving a voice to community members (those who contributed to the construction and those who did not) to express their motivations or hesitations in participating and their overall perceptions of the project. In addition the questionnaire provided important baseline information such as household activities, education, any changes felt from the sand dam and access to resources (including financial, water, land etc).

4.2 Semi-Structured Interviews

Semi-structured interviews were conducted with a range of stakeholders. Initial consultations with project leaders led to the development of a list of key informants. Subsequent interviews were devised through a 'snow-ball' effect where proponents being interviewed suggested other organizations or people that could provide insight. This form of purposive sampling was found to be an effective way of discovering people with rich information.

Key informants ranged from NGO's, governing institutions to community members and groups, all who either had a direct or indirect role in water resources management. The interviews provide an

opportunity for respondents to speak to their understanding of the situation facing arid and semi-arid areas in Kenya, the available water management strategies, the nature of community involvement, the motivations or constraints to community uptake of sand dams and other related water management activities and the programmes initiated by their institution. In addition, the interviews identified key organizations and government ministries working in the surrounding areas and established their roles and responsibilities. The interviews also provided an opportunity to determine how the various institutions interact, if at all.

4.3 Focus Group Discussions



Figure 20. . Focus group discussion Kitundu village - March 16, 2009

Date	Sand Dam Committee	Location	Total Number of Participants
March 16, 2009	Kwa Ndunda	Member's homestead, Kitunda village, Kitui District	25
March 20, 2009	Musingu	Keutunda market, Kitui District	14
April 6, 2009	Kwa Mutingo	Sakai Primary, Nthongoni village, Makueni District	17
April 7, 2009	Kwa Dison	Mavitini Primary, Muiu village, Makueni District	14
April 8, 2009	Kwa Ndeto	Kathamba primary, Kathamba village, Makueni District	17

Both institutions required that the communities form sand dam committees that will be responsible for the sand dam project. The focus group discussion provided a place for the sand dam committees to come back together to reflect on the process, positive and negative experiences and lessons learned.

The members of the executive committee, as well as the local administration (chief and assistant chief) were invited to attend. This included the chairperson, treasurer and secretary. It was originally decided that other members of the committee would be invited at random to form a group as large as 10 people but not exceeding 15. However not wanting to exclude committee members who were eager to participate or to be seen as ‘playing favourites’ all members were invited to attend. There was no financial incentive for members to attend the focus group but lunch was provided as the discussions were several hours long.

The program (Appendix D) for the focus groups began with a prayer, introductions and a mapping exercise. The introductions provided an opportunity for the research to be explained, as well as for the participants to offer the group’s history. The mapping exercise was used as a starting point to identify all potential, existing and malfunctioning water sources in the area. Two outlines of the community were drawn on large pieces on Bristol board in preparation for the focus group discussion. The group was then broken into two smaller groups and provided with time to add water sources and other landmarks to the maps (Figure 21). These maps (Figure 22) provided the basis for the initial part of the discussion of establishing overall community characteristics. The three main objectives of this first part were to determine problems with water resources, felt impacts of climate change, community organization and management of collective resources and community visions for the future.

The second part of the discussion focused on the sand dam project. Participants were provided with opportunity to speak about their experiences with the project, new partnerships that may have formed,

benefits from participating and any new projects that may have been catalyzed. The final part of the focus group program was a group photo which was developed and sent to each group.

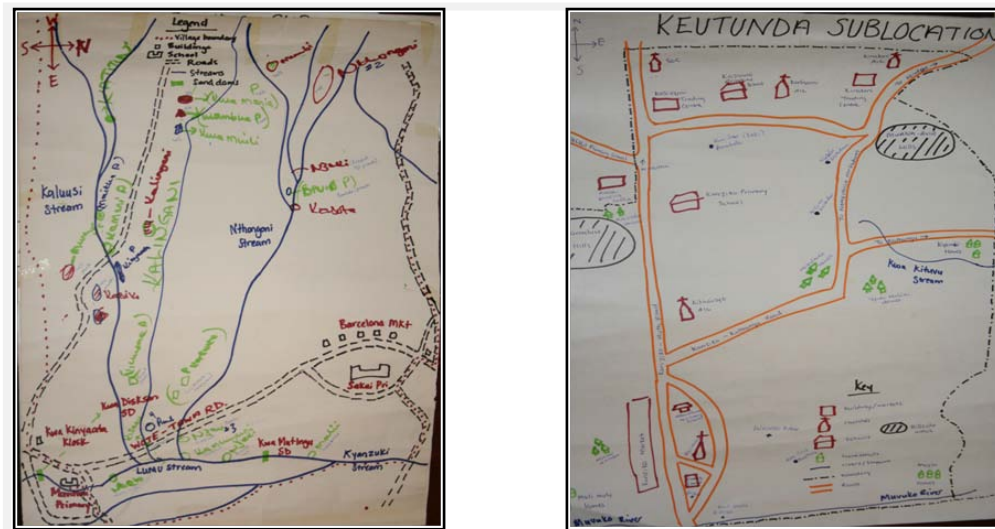


Figure 21. Example of maps from focus group (Nthongoni village and Keutunda sublocation)



Figure 22. Mapping Exercise in Keutunda sublocation - March 20, 2009

4.4 Personal Observation

Several weeks at the beginning of the fieldwork and the last two before flying home were spent in Nairobi interacting with researchers from the projects and other stakeholders. Considerable time was also spent in the main urban centres of Kitui and Makueni districts, Kitui town and Wote. Time spent

in these urban areas permitted meetings with district officials and project proponents as both implementing bodies have offices in these towns.

While completing fieldwork in Makueni district, I was able to stay in a primary school in one of the villages in Sakai sublocation. This experience provided an opportunity to embody a deeper understanding of the challenges faced by these rural communities. Through fetching water from the local sources (with enormous help from the local women), cooking over a charcoal fire, purchasing food in the local markets and being able to participate in community living, I gained invaluable insight into Kamba culture. I was also fortunate enough to be able to participate on a few of the sand dam construction days in Kathamba village. This not only offered a chance to see the construction



Figure 23. Myself and members from Kathamba village carrying stones we've collected back to the sand dam construction site

process but also facilitated the development of a deeper relationship with the Kathamba community, who were shocked by the hard work I wanted to do (Figure 23).

Unfortunately, due to time constraints I was unable to have the same experience with the communities in Kitui district. During the case study in Kitundu village, I travelled every day from Kitui town a half hour journey by *matatu* (Nissan minibuses – local transport). While I was able to stay locally in Keutunda sublocation, I was not able to stay for the same length of time as in Makueni district.

4.5 Translators

The use of translators was necessary in order to facilitate communication between community members and myself, as the majority spoke only Kikamba or Kiswahili. As I had had no previous experience with any of the communities, finding translators became largely the responsibility of the hosting institutions.

In Makueni, timeliness became a bit of a concern and in the end the assistant chief of Sakai arranged two research assistants. Neither Francis Mangi or Cecilia Ndiku, had any previous experience working as a translators but both had strong ability to communicate in Kikamba, Kiswahili and English. They were also local residents and were therefore familiar with the communities. I benefited greatly from their relationships as it facilitated an easy entry. Their aid in completing the household questionnaires and in general participation of community life was exceptional but given limited experience, a community advisor from the ALRMP was used to facilitate the focus group discussions.

SASOL, kindly, arranged for Joshua Wambua Nzomo, to be my translator in Kitui. Joshua was proficient in all three languages and had had previous experience working with an NGO doing health based community research. Joshua facilitated entry into the Kitui communities, translated the household surveys and several interviews, and capably ran the focus group discussions.

There was no formal training for any of the translators, however, a meeting was held with each assistant prior to the questionnaires. During the meetings I reviewed the goals of the research and the roles and expectations. In addition, each research instrument was evaluated. The translators and I went through each question to ensure that they were posed correctly to get the answers sought and to ensure that we had a common understanding.

5. Findings

The following sections outline the findings of the study in relation the three main objectives. The first section identifies the vulnerabilities that contribute to the susceptibility of the case study communities' to water scarcity. This section provides rational for the need for adaptation and development project such as the sand dams. In the second section, the effectiveness of sand dam development and adaptation projects is evaluated and their positive and negative features are discussed. The final section illuminates some of the factors that are constraining and contributing to project success and to the development goals of sand dams of providing water and catalyzing other ventures.

5.1 Characterizing vulnerability to climate change in Makueni and Kitui

When asked about solutions to the lack of water and the dry environment, one respondent said “the only solution is to relocate everyone from this place and NEVER come back” (Keuntunda respondent, personal communication, February 21, 2009)

Using the dimensions outlined in the literature review, namely environmental, historical, social, economic, infrastructural and technical, and political and institutional dimensions, this section provides an overview of some of the causes of vulnerabilities to water scarcity in each of the case study location. The analysis satisfies the first objective of this study and provides necessary situational information for the research on the sand dam projects.

5.1.1 Environmental dimensions

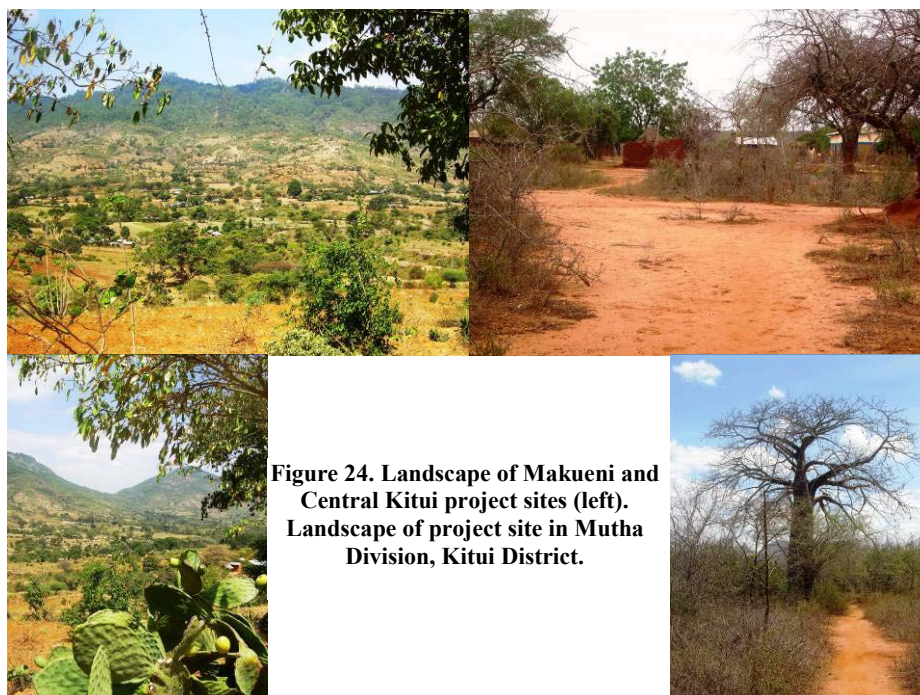
Makueni and Kitui Districts have been described as displaying an environmental gradient of decreasing altitude, increasing temperatures, and decreasing moisture from west to east (Rocheleau et al, 1995). Four of the five sand dam projects are located in Upland areas in the central part of the districts in the area surrounding the district capitals, Wote in Makueni District and Kitui town in Kitui

District. These locations are characterized as hilly regions which display a variance in elevation between 600 and 1,800 m. The fifth sand dam project, the sand dam in Keuntunda sublocation, Mutha Division, Kitui District, is located in the flat, lowland of the eastern part of the district at an altitude of between 500 to 600 m.

The climate in all five study sites is semi-arid, characterized by high temperatures and low erratic rainfall. On average the temperature in Makueni District is 22.1°C, while Kitui's is slightly higher at 24°C (Borst and de Haas, 2006; Ministry of Planning and National Development, 2002). The high temperatures result in high potential evaporation rates, which exceed rainfall and cause scarce surface water to dry up quickly. Lasage et al (2008) report that potential evaporation in Kitui District can be 1500 to 1600 mm a year, exceeding the average precipitation of 1000 mm a year. Rainfall in both districts ranges with altitude and topography and is seasonal with two rainy seasons. In the Upland areas rainfall can range from 800 – 1200 mm, whereas the lowland areas, such as in Keutunda sublocation, receive less than 730 mm of rain per year (Ministry of Planning and National Development, 2002). The rains fall in October to January, known as the *short* rains, and March to May, known as the *long* rains. The *short* rains are generally considered more reliable and account for approximately 70 percent of annual production. In all the study sites precipitation occurs as intense storms causing excessive runoff, little infiltration and massive losses of water downstream (Mutiso, n.d). Drought is a recurring theme in semi-arid climates as it is common for rains to fail. On average both districts experience drought every 4-5 years (Lasage et al, 2008).

The Upland areas can be characterized as thornbush savannahs, while in the lowland areas thornbush savannah grades into semi-desert vegetation. The vegetation is sparse and consists of mainly Acacia's, other thorny bushes, baobab trees and a variety of succulents. The climate and vegetation has been altered by the clearing of land for agriculture and settlement and by the felling of trees for firewood and charcoal production. Gazetted evergreen and mist forests account of only 2.2 and 1 percent of Makueni and Kitui district's total area (Ministry of Development and Planning, 2002,

2002a). The project sites vary in environmental conservation efforts and abilities. The Upland project sites, in Makueni and Central Kitui Division, have considerably more green vegetation which can be accounted for by the higher precipitation. Over 60 percent of farmers within the project sites in Makueni have terraces in their *shambas*¹⁸ and have planted fruit trees and other trees, this percentage appears to be comparable for the project site located in Central Kitui Division. In contrast, few farmers in the project site in Keuntunda sublocation, Kitui District have fruit trees planted and 18 of 22 household respondents mentioned making charcoal as one of their main livelihood strategies. Kitui District produces over 300,000 bags of charcoal annually, the majority of which come from Kitui's Eastern Divisions, such as Mutha. Figure 24 depicts the differences in landscape between Kitui's Central Division and Makueni, and Kitui's Mutha division.



Water sources are scarce in both districts. Out of the 92 households interviewed only 9 households felt as though they had access to enough water, while 79 percent of respondents felt that water shortage was one of the main challenges in their community. In Makueni District the only perennial

¹⁸ Vegetable garden

river is the Athi River. In Kitui District the Tana, the largest perennial river in Kenya, and Athi Rivers, both drain the district (Borst and de Haas, 2006). However, neither river is accessible to the populations in the study sites. Within the research sites, ephemeral streams, hard pans and earth dams, all collect water during the rainy season and dry up quickly during the dry season. Groundwater sources are also limited due to low yields and high salinity. Salinity is a key issue in the Keuntunda sublocation, Mutha Division, Kitui District, project site as the area is underlined with limestone. The study sites in Makueni District lie on a hillside and valley between two hills, Kitondu and Nthangu. Gazetted forests occupy the tops of these hills and act to collect rainwater which is distributed to the communities through natural springs.

5.1.2 Historical dimensions

“The story of the Akamba people and their lands provides important lessons about the interaction of environmental change with state policy, especially the impacts of sedentarization, privatization, and the commercialization of agriculture, on rapid demographic change (numbers, composition, and distribution of population within the region). The most significant changes in land use at regional scale have included the movements of highland Akamba to dryland areas, an ongoing land survey and tenure reform, a gradual shift from agropastoral to mixed farming production systems, the continuing conversion of dry forest savannas to agriculture, the progressive replacement of subsistence by commercial production from household to regional level, the “mining” of dry forest and savanna trees for commercial charcoal markets in the city, and the quarrying of sand from dry river-beds and channels to construct new housing and commercial buildings in the city” (Rocheleau et al, 1995)

In the 17th and 18th century, the Akamba people migrated from the south of Kilimajaro to the uplands of present day Machakos, Makueni and Kitui Districts (Rocheleau et al, 1995; Tiffen et al, 1994).

Here, the traditional land-use system of integrating highland agriculture with lowland cattle grazing, and using a mixture of household grazing and cultivated plots with communal pastureland, came into being (Lambert 1947a,b; Wamalwa, 1980; – as quoted in Rocheleau et al, 1995). The system served to spread the risk associated with drought, which is endemic to the area.

Their vulnerability increased in 1895 when the British declared the area of today’s Kenya as the East African Protectorate and as a result in 1901 and 1914 the Akamba lost approximately 1 million acres or two thirds of their original land, including the most fertile and half of the pastureland (Munro,

1975; Spencer, 1983; Wisner, 1977; - as quoted in Rocheleau et al, 1995). The British confined the Akamba and their animals to Native Reserves too small to support their population. Their land requirements were underestimated as the British did not have an understanding of their traditional land-use system and because at the time the number of cattle present was severely depressed due to rinderpest infection (Morgan 1963; Munro, 1975; Silberfein, 1984; Spencer, 1983; - as quoted in Rocheleau et al, 1995).

Population increase, the loss of access to large tracts of seasonal grazing land, government quarantining of indigenous cattle, agricultural intensification and sedentism resulted in land scarcity and degradation. By the 1930s, land scarcity and official policy promoting private permanent enclosed farms increased vulnerability of pastoralists, who lost access to streams, dry season grazing areas and cattle migration corridors. By independence, drought, crop loss and famine were common in Ukambani (Rocheleau et al, 1995; Tiffen et al, 1994).

Generally, European farms received all the policy benefits such as free veterinary services and a monopoly on cash crops (Rocheleau et al, 1995; Tiffen et al, 1994). In 1946, driven by land degradation and the cost of famine relief, resources were provided to the African Land Development (ALDEV) Board for investment in Kenya's ASALs. The ALDEV focused on 'destocking', building terraces, and other water conservation and infrastructure projects (Gichuki, 2000; Rocheleau et al, 1995; Tiffen et al, 1994). In 1954, low production on reserves and rural unrest across Kenya led to the creation of the Swynnerton Plan. The plan sought to consolidate, privatize and register land, as well as loosened the restrictions on African cultivation. The objective of the plan was to create a class of successful, elite African farmers and a landless and nearly landless class, who could provide labour to the large-scale farms or establish non-farm enterprise (Rocheleau et al, 1995). The goal was not realized as the displaced moved to more fragile areas instead of entering into wage labour. Kenya's independence government (1961) continued with the logic of the Swynnerton plan focussing on the settlement of white farms (Tiffen et al, 1994). Tiffen et al (1994) noted that the Swynnerton plan

diverted more resources to higher potential areas, as opposed to the ASALs. In Ukambani the continuation of the Swynnerton scheme further entrenched poverty, hunger, and environmental problems (Rocheleau et al, 1995a). By the 1980s, 40 percent of the farmland was controlled by 0.2 percent of farms (Rocheleau et al, 1995).

The 1970s and 1980s crises of environmental degradation, namely soil erosion, sedimentation of hydroelectric dams, deforestation and fuelwood shortages, was often associated with poor agricultural practices of small scale farmers (Rocheleau et al, 1995a). In contrast, the vulnerability was largely a result of a political climate that allowed land concentration, land scarcity and promoted agricultural intensification. The problem of soil erosion and increased sedimentation in streams resulted in policies to promote intercropping and terracing. Deforestation was viewed as an ‘energy crisis’ caused by a high demand for fuelwood and charcoal. The government thus funded widespread planting of fast growing trees however the clearing of agricultural land has been suggested as the main cause of deforestation.

The 1974-1976, drought and environmental degradation returned attention to Kenya’s ASALs. In 1978, the Machakos Integrated Development plan was the first major national development plan to focus on arid and semi-arid areas.

5.1.3 Social dimensions

Demographics

Approximately 839,155 and 555,000 people inhabit Makueni and Kitui Districts, respectively (Ministry of Planning and National Development, 2002, 2002a). Both districts display relatively high population growth rates of 2.8 percent in Makueni and 2.2 percent in Kitui. The population densities in Makueni District vary from 60 to 430 persons per km², the higher density occurs in the hilly regions where there are more natural resources. The density experienced by the Makueni study sites is approximately 200 persons per km². In Kitui District the population densities range from 6 to 153

persons per km², the former can be likened to densities experienced in Keuntunda sublocation case study location while the higher equates to those in Kitunda village, Central Kitui Division.

The average household size for all study sites was found to be 9.3 (Kathamba 9.2; Nthongoni 15.3; Muiu 11.2; Keutunda 7.2; Kitundu 6.4) which is higher than the reported district average of 6 – 7 for Makueni and 7.3 for Kitui District (GoK, 2008b; Nyaga, 2005). In several occasions the households consisted of more than one nuclear family (father, mother, sons, and daughters). Predominantly the other families were those of the sons, however as polygamy is an accepted part of the Akamba culture, the sub-units may also have belonged to multiple wives and their children (Barsby, 2008; Tiffen et al, 1994). In addition, a man's social and economic status, as well as his networks and sphere of influence are tied to the size of his family. Large households increase vulnerability as scarce resources need to be divided among more people, however, the extra family members could also provide remittances if members are able to migrate in search of employment. Kitui's population is predominantly young, with 54 percent children and 47 percent adults (Nyaga, 2005). The same can be seen in Sakai sublocation, Makueni district, where 54.7 percent of the population is below 24 years (Resilience project, n.d.a). A high level of dependents can increase vulnerability and impact spending such as through increased costs associated with education.

Most of the household respondents had some level of formal education and only 20 percent were unschooled (Figure 25). The large majority of unschooled respondent came from the three communities in Makueni District.

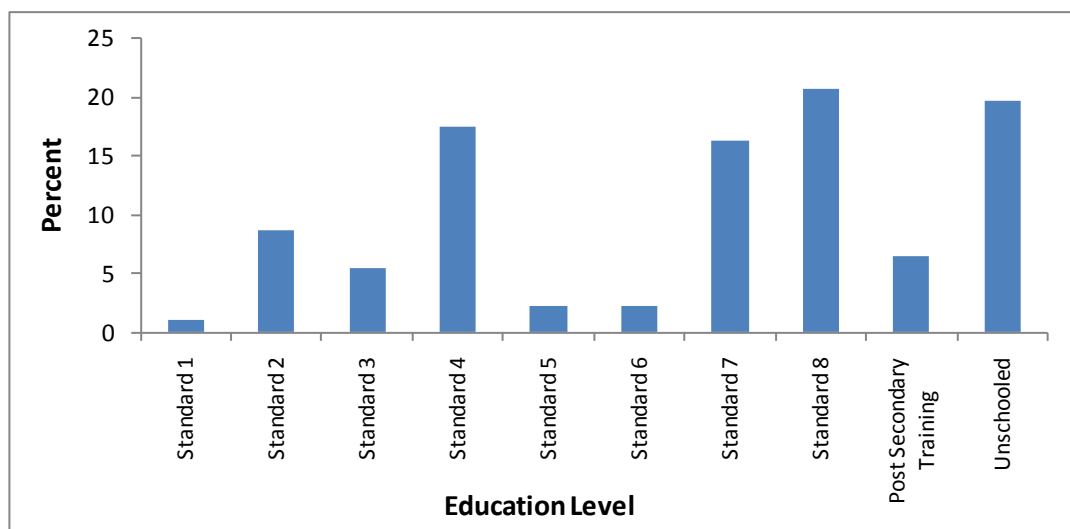


Figure 25. Distributions of education levels from respondents in all case study locations

Class and Gender

Over half of the respondents (55.4 %) felt that households in their community were not given equal opportunity to make community based decisions (Figure 26). The educated and the rich were perceived as being able to make more decisions and have more of a voice than the unschooled, illiterate and poor. Only Kathamba and Nthongoni had more respondents believing that all households were given equal opportunities. Animosity, created by perceptions or reality of inequality, can severely impact community spirit and the effectiveness of collective action.

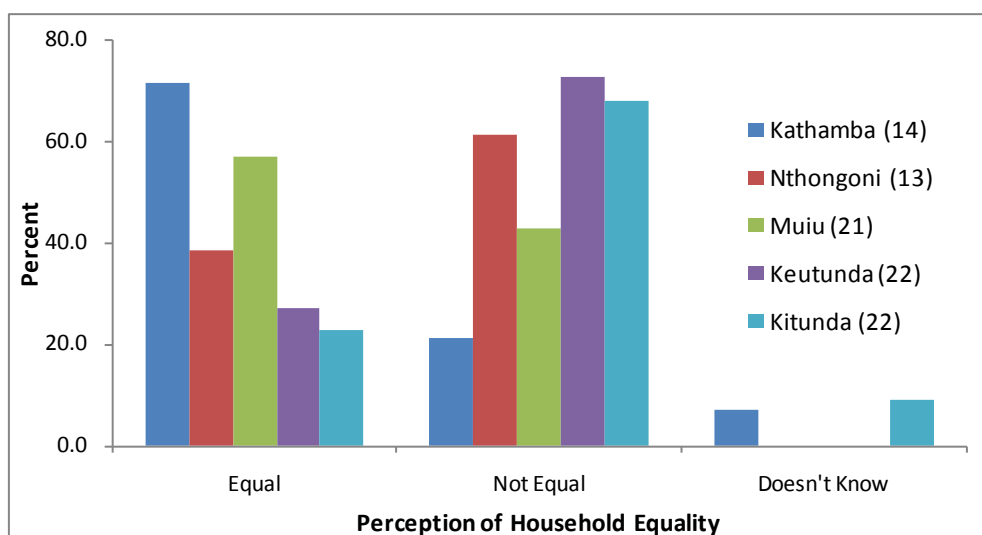


Figure 26. Perceptions of household equality for each study site

In terms of water resources, the wealthy often had improved access through the ability to invest in water supply infrastructure on their own land, to purchase water, or by owning donkeys, bicycles and wheelbarrows that facilitated the hauling of more water per trip.

Household composition was slightly more dominated by males (51 %) than females (49 %). Despite this, the households interviewed, overwhelmingly indicated that women were the primary water collectors (72.8 %), spending an average of 3.1 hrs and walking an average distance of 4 km per day in search of water (Figure 27). Congestion at the water sources can also greatly impact the time spent collecting water. Only 12 percent of respondents had access to another means of transporting the 20 litre containers used to carry water from source to homestead. The remaining 88 percent carried the containers in the traditional way using their head, backs and shoulders.

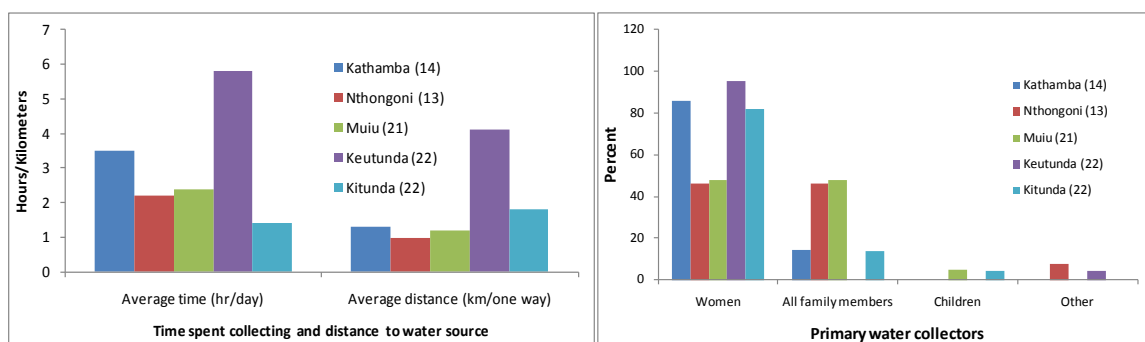


Figure 27. Average time and distance incurred by primary water collectors daily (left). The household position of primary water collectors (right).

Nyaga (2005) reported that “women carrying a 20 litre container expend about 200 calories per hour”. The high energy expenditure associated with searching for water and inadequate food consumption during drought increases a women’s vulnerability. Rocheleau et al (1995a) noted that during drought women in Kenya are the ones primarily responsible for finding food, managing the farm and fetching water. As sources dry up, women and children spend more time in search of water and less time on income generating activities. Even those women who receive remittances still needed to contend with reduced purchasing power during drought.

Women in both districts are also marginalized in terms of their control of productive assets such as land and capital and in terms of their influence in both household and community decisions (D.Mulonzi, personal communication, December 17, 2008; Ministry of State for Planning, National Development and Vision 2030, 2008a,b). The majority of households interviewed reflected this district wide perception of gender inequality (Figure 28). Only Kathamba residents responded positively with 78.6 percent deeming women as completely equal.

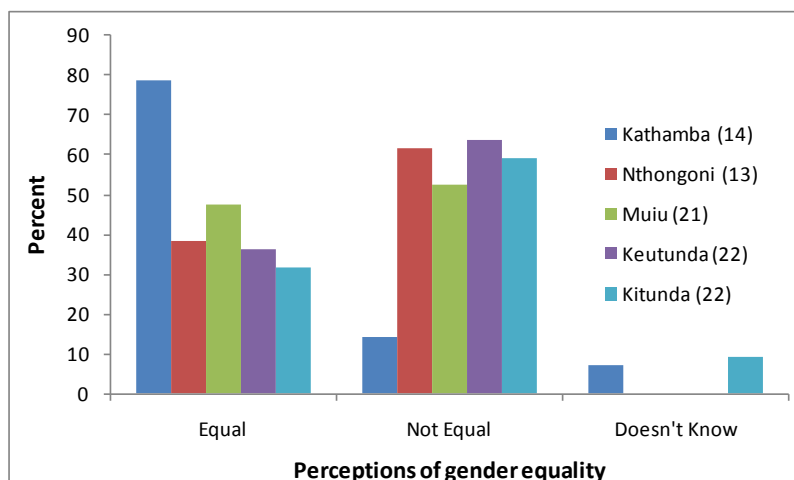


Figure 28. Household perceptions of gender equality within each study site

The Mbooni district development (Ministry of State for Planning, National Development and Vision 2030, 2008b) plan illuminated the impact of gender bias by stating that “the reason why rural based development activities have remained low is due to the position that women hold in the family set up and in the community in general”. They argue that women provide the labour and manage 80 percent of rural development activities such as small-scale farming and livestock rearing but hold no control of the production assets and can therefore not make decisions regarding them nor access credit to develop them.

Social Networks

Self-help groups (SHG) are an integral part of Akamba culture and serve to reduce collective and individual vulnerability to water scarcity and famine. Many SHGs began with the initiative of a small group of community members determined to overcome challenges in their communities. Most are family clan based or women’s groups engaged in soil and water conservation, land rehabilitation and income generation. In the past these groups aided in connecting individuals with access to food, fodder, fuelwood and employment during drought, as well as to government and NGO relief food (Rocheleau et al, 1995).

Out of 92 households surveyed only 14 were not part of one or more SHGs. The focus of the SHGs were varied, including merry-go-rounds (micro-credit schemes), poultry and dairy cow rearing, tree nurseries, group help with cultivation and building terraces, dowry and funeral payments, bee keeping and horticulture. In Sakai sub-location, Makueni district there are a total of 29 registered SHG (P. Ndiku, Assistant chief of Sakai, personal communication, January 27, 2009). In an interview with Mbaa Kimei SHG (Nthongoni village) one member explained “that as a group we are more likely to be recognized and helped by the government during dry periods and if the



Figure 29. Pictures of three SHG in Makueni District. Bindii Linga women's group (top left); Tei Wa Aka Ma Musii (top right); and Wendo Wa Kathamba women's group (bottom right).

government doesn't help then as a group, we can cultivate together and get food” (T. Mwonga, personal communication, March 28, 2009). A member of another SHG in Sakai sub-location described that she joined because “as a group you have power, if she is having difficulties she is able to turn to the group for help” (P. Mutua, personal communication, March 30, 2009).

Of the 14 households reported to not participate in a SHG the highest proportion were from Keutunda sub-location. Keuntunda also displayed the highest discrepancy between the number of respondents

that viewed households in the sub-location as being equal (27 %) and those that viewed them as unequal (73 %).

Psychological dimensions

Community perceptions of problems and their causes can influence attitudes and motivation in terms of trying to overcome and find solutions to the problems. In all case study locations the problems reported the most were water shortage by 79 percent of households and hunger by 38 percent. Other concerns mentioned (in descending frequency) were distance from hospitals, unemployment, poor roads, poverty, unclean water, illness, and lack of education, firewood and markets. In terms of water shortages, the primary reasons identified were lack of rainfall, rainfall shortage and rainfall distribution (59%). Other causes of water challenges mentioned were lack of trees (16%), lack of water infrastructure (12%), and climate change (12%) (Figure 30).

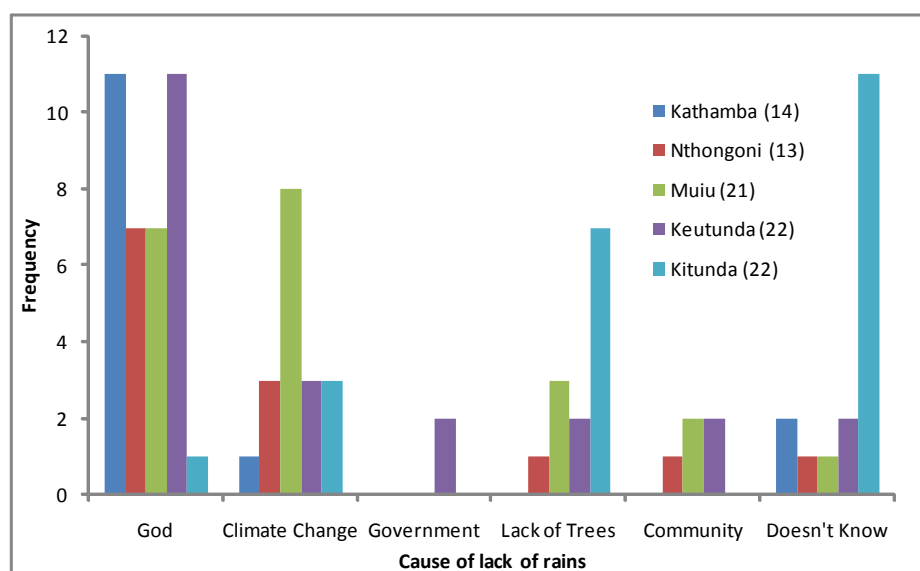
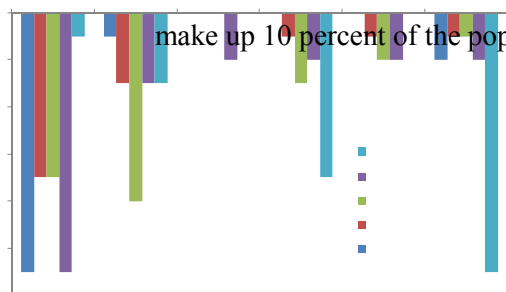


Figure 30. Household perception of why there is a lack of rain

Kenya's population is also deeply religious which impacts the way challenges are perceived. The majority are Christians (80 %), while Muslims and those that follow traditional African religions each make up 10 percent of the population. 40 percent of household indicated that God controlled the



rains, when respondents were asked ‘Who/What is the cause of the lack of rains?’. If communities view water resource problems as ultimately tied to God, they may develop a sense of powerlessness or attitudes of fatalism. Belief that there is little the community can do to change their situation contributes to a community’s vulnerability to climate change.

5.1.4 Economic dimensions

Agriculture

The main source of income in all five locations is farming (96.7%) and pastoral activities (91.2%). Only one respondent (from Keuntunda) claimed to not have access to any agricultural land. This is in contrast to the Resilience project’s documentation which indicated that 40 percent of household in Sakai sub-location, Makueni district did not have access to agricultural land (Resilience project, n.d.a). The size of land owned by the households varied from less than one acre to 50 + acres, with the majority of households (66 %) owning between 1 and 5 acres. All of the respondents indicated that they owned the land they cultivated, this however, also contrasts with the Resilience project’s documentation which indicated that only 1/3 of the households held title deeds (Resilience project, n.d.a).

Maize (93.5%), beans (84.8%), and cowpeas (91.3%) were the food crops most reported by households, in contrast to the low reliance on millet (19.6%) and sorghum (22.8%) which are more drought tolerant¹⁹. It was found that more than 56 percent of the households in Sakai sub-location, Makueni district consume all their agriculture produce rather than being able to sell some (Resilience project, n.d.a). In addition, it was found that 24 percent consume all crops within 2-3 months and therefore do not engage in any storing measures. The lack of stored crops and consumption of all production are both indicators of vulnerability and mean that households are not able to secure income to buffer times when crops fail.

¹⁹ It should be noted that the accuracy of food crops reported may not capture the entire picture. Several times during household surveys the research assistants and I would have to prod for further illumination. While maize, beans and cowpeas were the predominant answer, we would often have to note the presence of banana and mango trees in the shambas, in order to have more elaboration on what was being grown.

Households involved in livestock kept cows, poultry and goats, both for subsistence and commercial purposes. Two-thirds of households were found to keep livestock for milk, eggs, manure, ploughing and meat. Assessment of livestock and the price of certain food commodities are used as vulnerability indicators in times of drought (V. Mutaki, personal communication, March 31, 2009). Pastoralists become vulnerable during drought in two ways. First, there is a loss in production from livestock as there are low calving rates, poor production of milk and extreme weight loss. Secondly, the market value of cattle falls dramatically. In Kenya drought monitoring is completed on a monthly basis in target communities. Fodder and pasture conditions, the field crop situation, market food prices and the state of water sources are evaluated. Drought monitoring reports indicate that the price of livestock decreases and food commodity prices increase during dry periods. The normal average price for Maize in May is 12 Ksh in Kitui district and 22 Ksh in Makueni district. In May 2009, after poor rains, Maize prices in Kitui were 36 Ksh and 35 Ksh in Makueni, which equate to a 200 and 60 percent increase respectively (GoK, 2009). During drought, the market value of livestock declines. Cattle, which normally sell for 12,000 – 14,000 Ksh, were sold for 5,000 – 6,000 in January 2009 after the short rains failed. Goat and poultry values also decreased from 1,800 – 2,500 to 500 – 1,000 and 150 – 300 Ksh to 130 – 200 Ksh (Mutaki, 2008, 2009). Rural dwellers often sell their livestock at rock bottom prices in order to cope with drought and famine (Rocheleau et al, 1995). A loss of a third of a herd can take four years to recover (UNEP, 2000).

Other livelihood generating activities

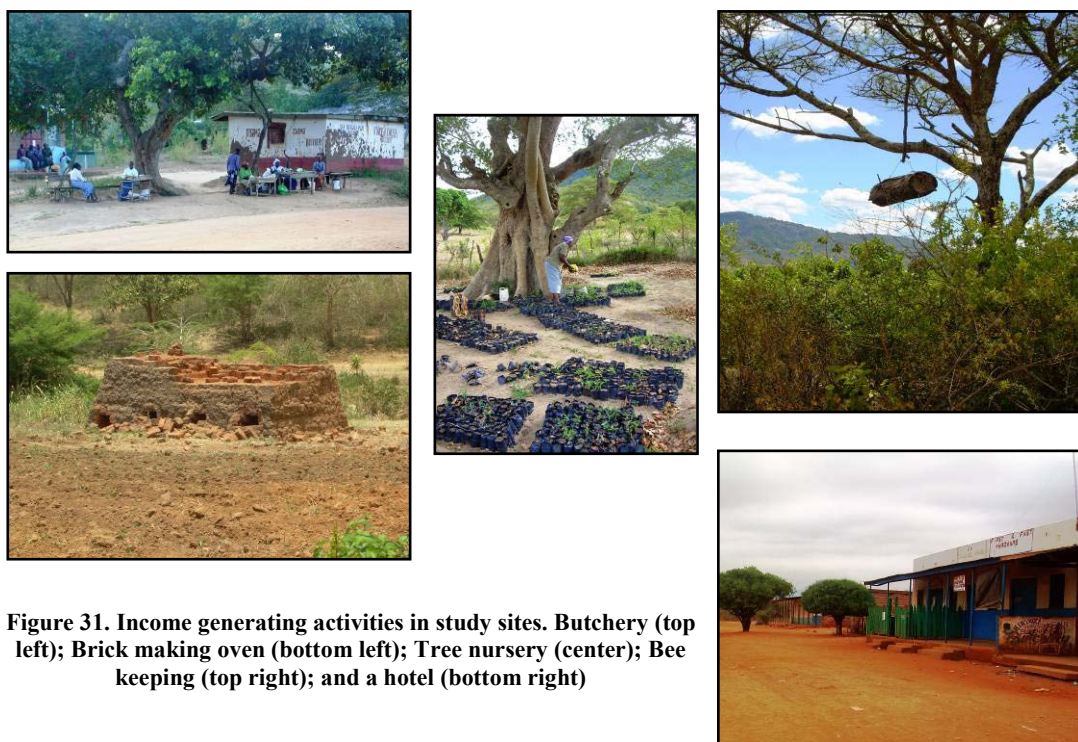


Figure 31. Income generating activities in study sites. Butchery (top left); Brick making oven (bottom left); Tree nursery (center); Bee keeping (top right); and a hotel (bottom right)

Diversification of livelihood is an important coping strategy for climate change. Over 78 percent of household respondents had between 2 and 5 sources of income and more than 15 different strategies were reported (Figure 30, 31, 32).

Income generating strategies	Location (no. of households)					Total	Percent
	Kathamba (14)	Nthongoni (13)	Muiu (21)	Keutunda (22)	Kitundu (22)		
Farming	14	13	21	19	22	89	96.7
Pastoralism	14	13	19	20	18	84	91.3
Vegetable selling	1	5	7	5	12	30	32.6
Fruit selling	3	2	9	5	7	26	28.3
Water selling		0	4	4	6	14	15.2
Basket making	1	1	3	1	17	23	25.0
Teaching	1	1	0	0	0	2	2.2
Tailoring	1	0	0	0	0	1	1.1
Business owner (e.g Shop, Hotel)	1	0	2	4	6	13	14.1
Casual labour	0	2	1	0	0	3	3.3
Matatu driver	0	1	0	1	0	2	2.2
Local beer selling	0	1	0	0	0	1	1.1
Pottery	0	1	0	0	0	1	1.1
Brick making	0	2	3	11	13	29	31.5
Charcoal burning	0	0	2	16	8	26	28.3
Rental income	0	0	2	0	0	2	2.2
Remittances	0	3	2	1	0	6	6.5
Selling firewood	0	0	0	0	0	0	0.0
Factory worker	0	0	0	1	0	1	1.1
Carpenter/contractor	0	0	0	1	1	2	2.2
Welding	0	0	0	2	0	2	2.2
Bee Keeping	0	0	0	2	1	3	3.3
Wood carving	0	0	0	3	2	5	5.4
Machine Operator	0	0	0	0	1	1	1.1
Dairy cow + milk selling	0	0	0	0	1	1	1.1

Figure 32. Other income generating strategies mentioned

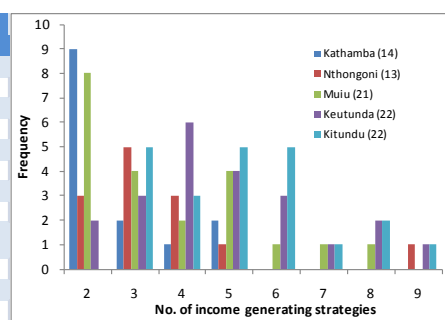


Figure 33. Total number of income generating activities adopted by households in the case study locations

Despite diversification, approximately 44.6 percent of households interviewed indicated an average monthly income of only 0 - 1,000 Ksh²⁰ (Figure 34). In Sakai sub-location, Makueni district 70

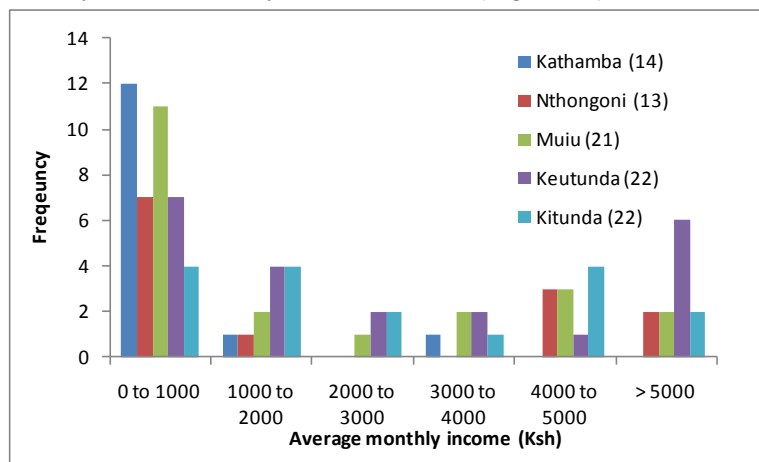


Figure 34. Average monthly income in each study site

percent of households spend 50 – 98 percent of their income on food, between 5 – 10 percent on health and 10 – 30 percent on education (Resilience project, n.d.a).

The heavy reliance on small-scale rainfed agriculture and low

purchasing power experienced by the majority of households in Kitui and Makueni districts means that there is a heavy reliance on food aid during periods of drought (Ministry of State for Planning, National Development and Vision 2030, 2008b). Lasage et al (2008) reported that during 2004/2005 over 50 percent of Kitui district inhabitants received relief food. In Kisau division (Population 50,510) in Makueni district 9 random examples of monthly drought monitoring reports (January, September 2006; May, June 2007; September, October, July 2008; January, March 2009) indicated food relief was received (ranging from 240 to 1,100 90 kg bags of maize) 4 out of the 9 months and one report indicated a serious need.

5.1.5 Infrastructural and technical dimensions

Roads, hospitals and markets

The road networks in both districts are predominantly earthed and mud roads which become impassable during the rainy season. Approximately 72 percent of households in the study sites in Makueni district are 1-5 km from the nearest village market and about 20 km from the district's main markets and hospitals in Wote and Mbumbuni. The study sites in Kitui district are also located quite

²⁰ Four households from Kitundu village refused to answer.

far from a major market and hospital, the Kitunda village site in Central Kitui division is approximately 15 km away from Kitui town and the Keutunda sub-location site in Mutha division is approximately 25 km away from Mutomo, another large centre. Public transportation in Kenya is in the form of privately owned *matatus*²¹ and other small buses, which service the main roads. In order for household members in all three sites in Makueni District and the Kitunda village site in Central Kitui division to access public transport, they must first walk approximately 10 km to roads serviced by *matatus*, albeit still rarely.

Energy

Energy supply across both districts is inadequate. In Makueni district only 950 out of 144,320 households have electricity and 100 percent of households use charcoal and firewood for energy needs, while only 30 percent also use other sources such as kerosene, gas or biogas. The percentages in Kitui district are comparable with 98 percent of households using charcoal and firewood for fuel (Ministry of Planning and National Development, 2002, 2002a).

Water supply and quality

A large majority of people in both areas are water insecure. In Kitui district 85 percent of the population does not have a potable water source within 8 km of their homes (Few et al, 2006). The Makueni district Development Plan 2002 – 2008 shows that only 10 percent of households have access to potable water and on average the nearest source is 4.5 km away. Limited water availability greatly impacts development of the region and is expected to worsen with projected climate change and increases in population (Few et al, 2006; Lasage et al, 2008).

²¹ Nissan minibuses

Box 2. Main characteristics of existing water supply systems in Makueni (Gichuki, 2000)

- Many were constructed over 40 years ago and are reaching the end of their design
- Most water projects are serving more people than they were originally designed to serve, leading to rapid deterioration of facilities and frequent breakdowns
- Poor operational support and inadequate maintenance, resulting from insufficient funds and lack of capacity to operate, maintain and replace ageing equipment
- Dispersed nature of water points makes it costly and logistically difficult to monitor the operation of water schemes.
- High concentration of animals around watering points has resulted in overgrazing, causing environmental degradation, and siltation of pans and dams
- High lag time between siltation and de-siltation of dams, at high cost
- Shallow wells are only feasible in valley bottoms in more humid areas. Where groundwater is available at depth in excess of 30m, it is not feasible option for a poor individual or rural local community. Most boreholes were dug for government projects, then handed over to County Councils for operation and maintenance, and are now being handed over to the community.

According to Gichuki's (2000) study on water management in Makueni district, water supply systems are inefficient and strained (Box 2). The semi-arid rural areas of Ukambani do not have access to piped water systems. The dispersed settlement patterns with distances between households from 300 to 800 m (Gichuki, 2000; Personal observation), high installation and operation cost of piped systems has resulted in the predominant focus on communal watering points. Several households have also invested in private water supply systems.

The 5 case study locations used several techniques to obtain water. The most common sources of water for domestic use were sand dams²² (33.7 %) and scoopholes (37 %) which combined are a source of water for 70.7 percent of the households interviewed (Figure 35). Scoopholes are dug every season by community members and can be up to 10 m deep (Figure 36a).

²² Sand dams were only considered as a source of water when explicitly mentioned by the respondent. It should be noted however, that in several case it was clear that respondent using and stating scoopholes were access the water within the vicinity of the sand dam and thus the use of the sand dam is most likely considerably higher.

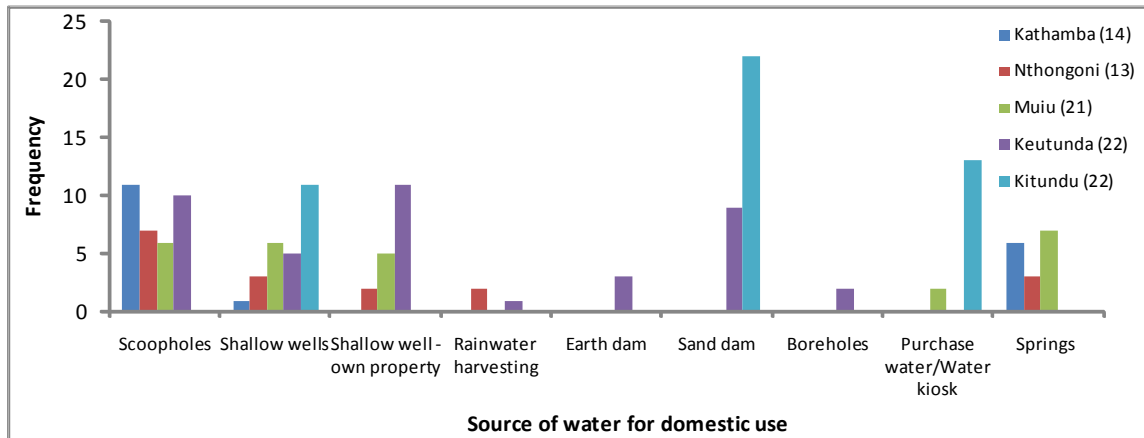


Figure 35. Distribution of use for each source of water in each case study site

Shallow wells, which are holes dug in the ground to reach the aquifer, are used by 37.7 percent of respondents. The shallow wells varied in structure, from those lined with concrete to simple holes dug deep in the ground (Figure 36b, 36c). While small scale rainwater harvesting in buckets or oil drums and water harvesting in fields were reported by the majority of households, few had large water storage tanks. There were 3 households interviewed that invested in roof catchments and on average each of the sand dam committees indicated that 10 percent of their community collected rainwater runoff from their buildings (Figure 37). The most common reason stated for the



Figure 36. Water sources in the case study locations. (a) Scoophole in Keutunda sublocation approximately 10 m deep, February 2009 (left). (b) Shallow well in Muiu village, March 2009 (middle). (c) Private landowner's shallow well in Nthongoni, March, 2009 (right).

lack of investment was cost. The Nthongoni sand dam committee estimated that on average a water tank would cost 40, 000 Ksh. This cost is exceptionally high for individual home owners making an average monthly income of 1,000 Ksh.



Figure 37. Examples of water harvesting off roof catchment systems in Nthongoni village (left) and Keutunda sublocation (right).

Water quality facilities and sanitation services were lacking in all the case study communities. Several local methods were employed by households to clean drinking water. The primary method was boiling, followed by the use of ash and on rare occasion the use of chemical treatments. Many households explained that the use of boiling is also often restricted because of the lack of firewood.

Access to information and technologies

It was noted that meteorological information in Makueni district is not communicated to farmers and when it is, it is not always in a manner that is understandable to them (IISD, 2007). The Resilience project (n.d.a) survey found that 88 percent of households in the Sakai sub-location, Makueni district received climate information from either radio, TV, newspapers and from agricultural extension officers. However, 66.7 percent agreed that they would like to have more and more specific and useable information (Resilience project, n.d.a). Lack of access to agricultural inputs, such as fertilizers and pesticides, and to credit was also mentioned as limitation to food production.

5.1.6 Political and institutional dimensions

Governmental

The five case study locations and Kenya's ASAL regions in general are vulnerable to water scarcity for the several reasons outlined above. The inherent environmental characteristics, historical legacies, social structure, economic activities, and poor infrastructural development are all the result of and are underlined by Kenya's development policies.

The country's financial resources are allocated based on government priorities and identified policy objectives. Unfortunately, this has resulted in country wide inequalities, with resources in the past being predominantly aimed at developing Kenya's more productive areas, while Kenya's ASALs have been economically and politically marginalized (GoK, 2009a). Until the National policy for the sustainable development of arid and semi arid lands of Kenya (2009), the policies guiding development of Kenya's ASALs were inappropriate. As a result ASAL's are the most underdeveloped areas of Kenya with lowest access to basic services and investment in infrastructure.

The current ASAL policy was developed in consultation with local communities, NGO's and government and identified seven main policy issues (Box 3). In general the policy recognizes the need for more effective land use systems and support for livelihoods. Land use systems need to include proper tenure and legal mechanisms to resolve ownership and quality disputes, as well as sustainable natural resource management. To encourage economic stability the policy focuses on supporting existing livelihoods, through improving infrastructure such as roads, water provision, animal health services and marketing, and by promoting diversified livelihoods.

Box 3. Main priorities of the National policy for the sustainable development of arid and semi arid lands of Kenya (GoK, 2009a)

- Restructure the ASAL economy over time towards a market-driven economy so that key inputs are accessed through market as well as through kinship and social networks.
- Reduce reliance on livestock through human capital development and diversification of sources of income.
- Improve natural resource management and utilisation by reviewing existing land use policies and land tenure systems.
- Improve pastoral productivity by conservation of the environment, domestic animal genetic resources and other biodiversity.
- Improve markets and provide social services to mobile pastoralists.
- Provide financial services to nomadic pastoralists.
- Reduce and manage risks such as drought and floods that often reduce assets and increase food insecurity.

The policy promotes the devolution of development planning and financial decision making to the lowest level of local government. It is hoped that decentralization will allow for faster decision making, accountability and better assistance during disasters. As drought is recurrent and the number of people affected is increasing (Table 3), the ASAL policy focuses on long term strategies to develop water sources through better infrastructure and new technologies. The national ASAL policy is also closely linked to the national disaster policy.

Table 3. Numbers of people affected by drought in Kenya, 1975-2006. Source: National Disaster Management Policy, Republic of Kenya, 2004 - as quoted in Oxfam, 2006 * estimated number from Associated Press, 2009)

Year	Number of people affected
1975	16,000
1977	20,000
1980	40,000
1984	200,000
1992	1.5 million
1995-6	1.4 million
1999-2000	4.4 million
2004-2006	2.5 million initially to 3.5 million currently estimated
2008-2009	10 million *

The National Policy on Disaster Management (GoK, 2009) was formulated to ensure that prevention, disaster risk reduction and climate consideration were integrated in national development

Box 4. The National Policy on Disaster Management in Kenya main principles (Source: GoK, 2009):

- An effective Disaster Early Warning, Information and Prediction System;
- Mainstreaming disaster management in development programming;
- Strong link between Early Warning and Disaster Response through harmonised and standardised rapid response interventions to disasters;
- A government-led institutional framework that allows effective coordination of the relevant stakeholders and enhances trust-building and collaboration among partners;
- Provides for and differentiates between procedures and mechanisms of response to slow - and rapid onset disasters
- Established and functional semi-autonomous agency responsible for disaster management with oversight from the Ministry of State for Special Programmes;
- Provides for flexible financial and response procedures to facilitate appropriate, effective and timely planning and management of disaster control initiatives; and
- Reinforces the disaster management strategies of vulnerable and affected communities.

programming. In terms of managing disasters the policy has made several recommendations such as the creation of funds, insurance initiatives, and the stockpiling of food (GoK, 2009). The two key funds proposed are the National Disaster Management Trust Fund, which is suggested to be 5 percent of the annual National budget, and the District Disaster Management Fund, which proposes that 5 percent of the existing Constituency Development Fund be allocated to disaster management. The policy outlines that key infrastructural constraints are limiting the

speed of disaster responses and expresses the need collaboration with all government ministries.

In terms of water management, Kenya's national water policy has recently been restructured. The tenets of the new system are: separation of roles and responsibilities; creation of new institutions; stakeholder participation; and river basin management approach. The view was that the problems of scattered and inadequate infrastructure and the poor functioning management system was due to a top-down approach that did not integrate local users and that was bound to political boundaries. As such the government delegated the management of water resources to two autonomous agencies, namely, the Water Resources Management Authority (WRMA) responsible for the allocation, protection and conservation of water resources, and the Water Services Regulatory Board, which is mandated to licence all providers of water and sewage services. For each catchment area WRMA

will appoint up to 15 persons to establish a Catchment Area Advisory Committee (CAAC). The committee will advise WRMA. Guidelines stipulate that appointed persons should include pastoral and agriculture community members, NGOs, businesses, municipalities and Water Resource Users Associations (WRUA). The WRUAs are the manner in which the new Act proposes to provide a role for community groups (J. Nakiyu, personal communication, April 15, 2009). The Act states that WRUAs will act as forums for conflict resolution and cooperative management of water resources. The Water Services Regulatory Board's is not permitted to deliver any water and sanitation services, but is vested with the responsibility of issuing licences to private Water Service Providers.

Despite the changes, the water management system remains state centric with all water resources being vested in the state. For rural communities, groups engaged in water service provision must obtain licences if they are supplying to more than 20 households, in addition any groups collecting water for more than minor domestic purposes must obtain a permit and be registered as a WRUA by law. Both the water allocation permits and water service provision licensing will be difficult for most WRUA or SHG to obtain. Land ownership must be established for the permits however land tenure in Kenya's rural areas is not well defined. In terms of obtaining a licence technical and financial competence must be evident, which will be difficult for many small rural groups. As land tenure, capacity, and financial resources are a concern, and corporate service providers are unlikely to supply rural communities, the new Act is said to be inadequate to reach the needs of rural communities in Kenya (Mumma, 2005).

Non-governmental

Non-governmental organizations play an important role in reducing vulnerabilities and in coordinating disaster relief. In Makueni and Kitui district capitals, Wote and Kitui town, there was a presence of several NGOs. In Wote the District Water Officer identified several partners including the Kenyan Red Cross, which has constructed boreholes and earth dams; AMREF, who has built several shallow wells with targeted communities; World Vision, which is involved in several

community water projects and pipe schemes; Excellent Development and Action Aid (Mutonga, Personal Communication, January 26, 2009). Despite this, only 4 respondents from the five case studies mentioned the presence of another NGO within their area. This indicates that social networks for accessing resources and aid are limited in the communities. Only the Kitundu village sand dam committee mentioned a partnership that formed as a result of working with SASOL. SASOL has a strong partnership with the Kitui Development Centre (KDC). This Kenyan NGO is based in Kitui town and works closely with neighbouring villages. For SASOL's projects that are close to Kitui town the KDC completes training on Health and Sanitation, Natural Resources Management and diversifying livelihoods (J.Muoma, Personal Communication, March 18, 2009). This partnership has expanded the social capital of Kitundu village.

5.2 Evaluating the sand dam adaptation strategy

Sand dams are being advocated as effective climate change adaptation strategies for arid and semi-arid environments in developing countries. The low cost and simple technology is promoted as being easily transferrable and accessible to rural communities which have limited financial resources but have access to labour and local materials (sand, rocks and water). The technology of harvesting and storing water below ground is deemed appropriate for the environment's short, heavy rainfall that quickly disappears through runoff and with the high evaporation. In addition the strategy's participatory nature is viewed as a building block, facilitating collective action and subsequent development activities. Using the evaluation criteria laid out in the literature review this section will analyze the appropriateness and effectiveness of sand dams as an adaptation strategy.

5.2.1 No regrets

ASALs are inherently susceptible to water scarcity and drought. The lack of perennial rivers and large reservoirs, the high potential evaporation and the short duration and high intensity rainfall means that water does not stay in the system for very long. Several water supply strategies such as shallow wells

and boreholes are extractive strategies. These methods rely on withdrawing groundwater however as the water table falls, these sources become dry. Even if climate change results in an increased annual amount of rainfall for East Africa, the rainfall will continue to be erratic, unreliable, and will flow downstream before the aquifer is fully recharged.

In contrast rain water harvesting (RWH) methods, such as sand dams, seek to store the water that falls in the system. A typical mature sand dam, with a height from 1-4 m above the surface, can have a stored volume of 100, 000 to 50,000, 000 litres and can be fully recharged from a single flash flood (Ertzen et al, 2005). Sand dam strategies are not only appropriate for the current conditions in ASALs but will be efficient in addressing water scarcity concerns associated with climate change and variability and therefore represent ‘no regrets’ adaptations.

5.2.2 Improving equitable access to fresh water

While the premise of sand dams is to increase the amount of available water in an area, the reality of this strategy improving equitable access to fresh water is dependent on several factors. First, a sand dam must mature in order to reach full potential and provide maximum water storage; second, a community must determine the rules and means of access in order to ensure equitable distribution of available water and third, catchment scale concerns must be taken into account.

Sand dams maturity

Sand dams need to mature in order to be an effective strategy. A single sand dam can take 5-7 years to mature, that is to fill with sand. Within this time catchment degradation and sand harvesting needs to be properly managed (Mutiso, n.d). Within the Tana and Athi watersheds, the potential of sand dams has not been realized, as the majority of them are experiencing siltation caused by catchment degradation and erosion (J.Nakiyu, Personal Communication, April 15. 2009). Unsustainable sand harvesting for construction has also impacted the amount of water a sand dam can retain (J.Nakiyu, Personal Communication, April 15. 2009).

Means and terms of access

Once a sand dam is mature equitable access is reliant on the terms and means of access. In all five case studies the majority of respondents claimed that everyone could access the dam, however there were fairly large percentages in Nthongoni and Muiu village and in Keutunda sublocation who felt that only those who participated in the construction of the sand dam should be able to access the water from the dam. In addition, in Muiu nearly a third of the respondents felt that the sand dam was located too far from their homestead to be of any use (Figure 38). Equitable access

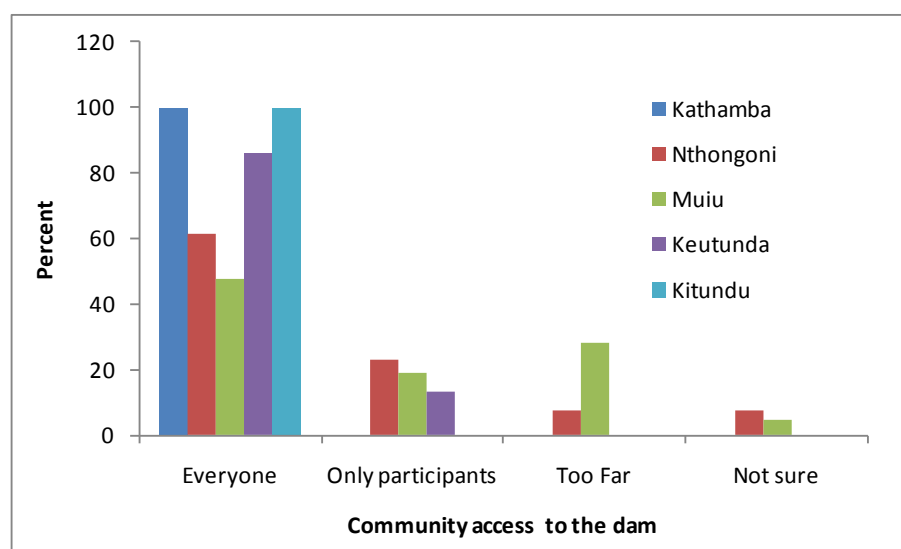


Figure 38. Perceptions of community access to the dam for each case study location. The responses included: everyone having access; only those who participated in the construction; everyone having access but a large percentage being too far; and not sure.

therefore needs to be considered at the onset and placement needs to take into consideration the number of households that the dam will benefit.

The means in which the water is accessed from the dam also needs to be considered. In practice, a sand dam should be built with either a shallow well on the bank or with a pipe that is accessible from the downstream side (Figure 39). These two methods ensure that the communities are benefiting from the natural filtration provided by the sand. The traditional means of accessing the aquifer through scoopholes becomes problematic because the water is exposed and susceptible to contamination. In

all five case studies cattle could be observed walking in the river bed and drinking directly from the scoopholes. In some locations this was minimized through the use of make shift fences which would protect the open water from being contaminated (Figure 40). All of the sand dam committees agreed, that one of the management rules were that livestock cannot access the dam. While enforcement is clearly a problem, all of the sand dam committees hoped to build an enclosure and trough adjacent to the sand dam where livestock can be watered.

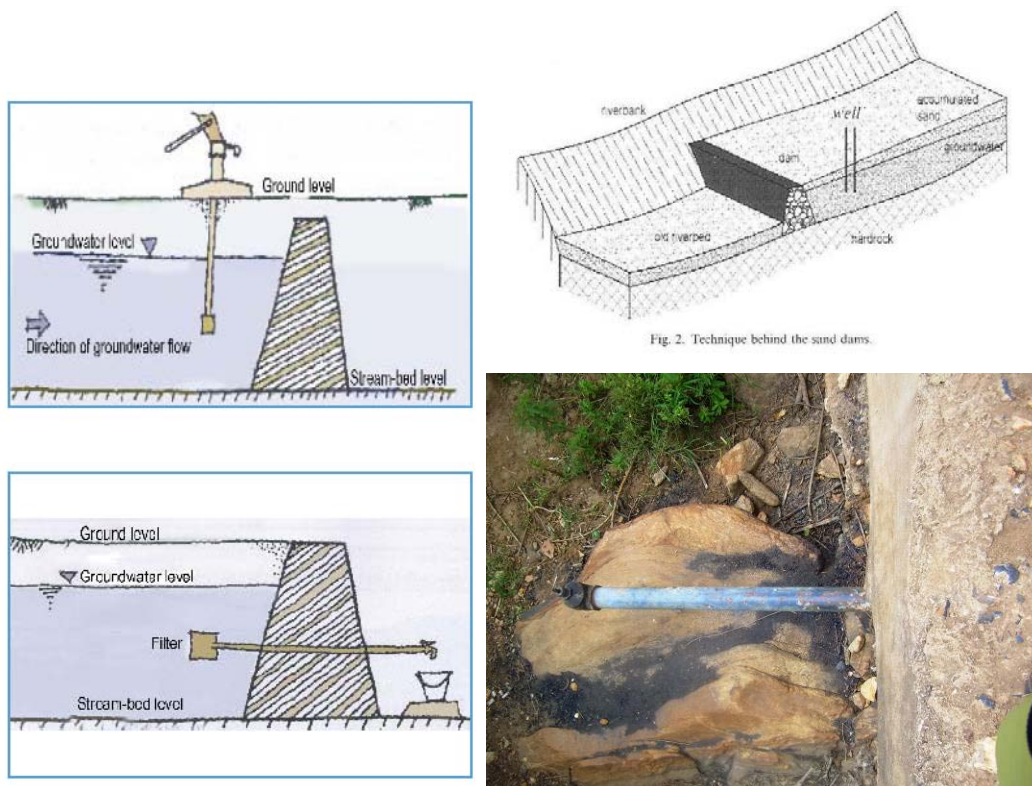


Fig. 2. Technique behind the sand dams.

Figure 39. Images displaying option for accessing water from a sand dam. A shallow well can be placed on the bank and can access the water from the raised water table (top) or a pipe can be fitted through the sand dam and the water can be accessed from the sand dam's downstream side (bottom). (Sources: Lasage et al, 2008 top right).

All of the sand dam committees expressed a desire to control who was taking water from the sand dams and the amount being taken. The two sand dam committees in Kitui District said that they will



Figure 40. Cattle in the river bed and drinking from scoopholes (left). Examples of make shift fences used to protect scoopholes and shallow wells (right)

not restrict access to the sand dam, while the three sand dam committees from Makueni felt that only the members that helped build the sand dam should access the water and that those that did not help must pay to become members²³ or must pay for the water. However, the committees expressed frustration in trying to enforce these rules. There is no means of restricting access to the sand dam, as anyone can dig a scoophole. The committee in Muiiu ultimately aimed to hire a watchman but recognized that they could not pay him a wage. The pipe which was installed with the Muiiu sand dam was not yet functioning but when it is, the committee hoped to lock access to the pipe as a means of controlling who can collect water.

Equitable access is also determined by the means with which households transport the water to their homesteads. One respondent from Kitundu noted that even with the sand dam not everyone has equal access because some people have donkeys and thus can carry more than those who have to carry the water on their backs (Kitundu respondent, personal communication, February 17, 2009). Only the group in Keutunda, the driest case study location, addressed this challenge. During the dry season when water sources are diminishing, each household is only allowed to collect four 20 litre containers. In addition, as the sand dam serves the entire sub-location of Keutunda each village is

²³ Muiiu committee suggested 200 Ksh per new member household.

allocated a specific day on which households can collect water. This rotating schedule eliminates congestion and ensures equity.

Catchment

On a catchment scale, a sand dam or a network of sand dams could potentially negatively impact water availability for downstream users. A study completed by Borst and Haas (2006) indicate that a single sand dam may reduce the flow downstream by 2 -3 percent. Ersten and Hut (2009) however caution that these results are for Kitui Central division which experiences relatively higher rainfall than southern parts of Kitui district such as Mutha division, where Keutunda sub-location is located. In areas with lower and more erratic rainfall the total annual percent collected by a single sand dam may be considerably more. Ersten and Hut (2009) also noted the importance of considering the entire watershed. For instance the loss in water to downstream users may not have been of beneficial use either because the short fast runoff is not harvested or because the runoff causes flat areas to be inundated.

5.2.3 Reduces socio-economic vulnerabilities

A mature sand dam in a community increases the availability of water throughout the year and improves the proximity of the water. Both of these factors have a positive effect on socio-economic vulnerabilities such as on household health and wellbeing, on agricultural production, and on the expansion of income generating activities. Unfortunately, poorly maintained and immature sand dams can also create community vulnerabilities.

As a community, the process of constructing a sand dam is said to create community cohesion and empowerment thereby building social capital which can be utilized for other development and socio-economic activities and reduces socio-economic vulnerabilities.

Health and well-being

Overall sand dams have a positive effect on community health and well-being. The increase in the availability of water and the closer location shortens the time spent fetching water, improves household hygiene practices and nutrition, and reduces the incidences of disease related to unclean water. There is, however a risk that sand dams can collect surface water behind the dam which may cause some community vulnerabilities.

Remple et al (2005) found that on average sand dams with water available saved households 2.4 hours per trip. This extra available time enabled women to spend more time on household chores such as meal preparation and washing of clothes, on agricultural activities such as preparing soil, harvesting and creating terraces, and on other income generating and self help group activities. One respondent from Keutunda noted that their household income had increased since the sand dam. He explained that the time saved from collecting water means that his wife can help with charcoal making and they are able to sell more (Keutunda respondent, personal communication, February 21, 2009). Manzi (2005) found that an approximate increase of 20 percent in the production of maize, beans and legumes could be directly attributed to the time saved and water available from the local sand dam. With the time saved from collecting water, children are able to attend school and spend more time on school work (Remple et al, 2005).

The improved quantity and proximity of water allows families to use more water for domestic and agricultural purposes. Lasage et al (2008) found that households in the Kiindu catchment had increased their domestic and agricultural water consumption by 50 percent ten years after their sand dam had been constructed. While all four case studies with a sand dam spoke of the increases in water, only Keutunda sub-location and Kitunda village in Kitui district were asked to quantify the increase. Households in Keuntunda village reported using 33 percent more water for domestic purposes six years after their sand dam had been built. The increase reported from Kitunda village whose sand dam is 15 years old was 55 percent.

The increase in use of domestic water has enabled positive changes in hygiene, such as washing hands, body and clothes. One member in the focus group discussion in Kitunda village said “now with the sand dam, if you go dirty it is because that is your wish. Children use to be very dirty, using clothes for 3 days but now 1 day and can wash” (Kitunda focus group participant, personal communication, March 16, 2009). This same participant claimed that there has been a reduction in lice and bed lice since the sand dam. The increased availability of water positively impacts the frequency of washing which in turn decreases skin infections and incidences of diarrhoea. Remple et al (2005) noted that the Medical Director of a clinic in Kitui district where sand dams have been built attributed the decrease in diarrhoea and skin ailments to increased water availability. However, of the 92 households interviewed only 4 respondents directly mentioned health improvements and improved hygiene practices.

Household wellbeing is also affected indirectly from the increased water availability. In the literature vegetable production is often cited as a benefit of sand dams and was mentioned by 12 respondents from the five case study locations, 9 of which were from Kitunda village. The sand dam committees in Muiu, Nthongoni and Kitunda village all mentioned that landowners adjacent to the sand dam have been able to grow vegetables due to the improved water table. The entire community benefits as vegetables are more readily available in the local markets and households no longer have to travel to the larger urban markets to purchase them. Increased consumption of vegetables and fruit improves nutrition and health. A village elder in Kitui district claimed that the increased consumption of vegetables and fruit has improved performances in schools as there are fewer eyesight problems (Remple et al, 2005).

The vulnerabilities created from a sand dam are the result of the surface water that collects behind the dam as it is maturing (Figure 41a). The collected water is stagnant creating a suitable media for the breeding of mosquitoes, which can cause frequent outbreaks of malaria (ALRMP, n.d). All the case study locations, except Kathamba village, also mentioned drowning as a challenge caused by the

surface water behind the sand dams. The sand dam committee in Muiu village explained that the sand dam is located along a commonly used path and that during the rainy season the water that collects behind the dam is a hazard to children. This can be avoided by constructing the dam in stages, thereby reducing the depth of surface water. The open water is also more susceptible to contamination from cattle and catchment runoff (Figure 41b). In contrast, mature sand dams should reduce the risk of contamination of stored water, as direct contact is minimized and parasites cannot breed underground.



Figure 41. Surface water collected behind sand dams in Kitui and Makueni District. a. Kwa Ndunda sand dam in Kitunda village (February, 2009). b. Contaminated water behind Kwa Mutingu sand dam in Nthongoni village (April, 2009).

Improved economic status

The improved water availability enhances household income in several ways. This is primarily through increased agricultural output, larger numbers of livestock and vegetables production near the sand dam, but also through diversification of income generating activities and reduced expenditures. It was found that household income, in a study evaluating the difference in two catchments over ten years, increased by 9,000 Ksh in the catchment with three sand dams and remained the same in the one without a sand dam (Lasage et al, 2008). Figure 42 depicts the household perception of economic activities that have benefited from the sand dam.

Lasage et al (2008) found that the percentage of irrigated crops (bucket irrigation), in a catchment with 3 sand dams approximately 10 years old, had risen from 37 percent 10 years earlier to 68

percent. Manzi (2005) found that communities were able to diversify crop production, decreasing their susceptibility to a total crop failure. In Kitunda village 41 percent of respondents indicated

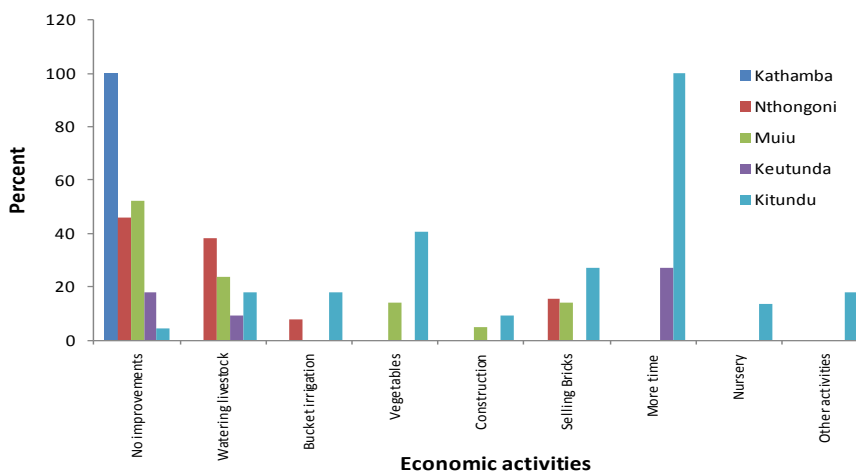


Figure 42. Improvements in economic activities resulting from the increase in water from the sand dam

they were able to grow vegetables as a result of the sand dam and 19 percent noted an increase in crop production. One local resident reported being able to grow tomatoes, *kale* and other vegetables for the first time. These changes can be attributed to both the increased availability of water and the savings in time which can then be spent creating terraces.

Livestock production also improved with the presence of a sand dam. In the four case study communities where the sand dams were complete, households interviewed noted being able to take livestock to be watered at the sand dam. Livestock become healthier and grow faster as they are not walking long distances in search of water. Farmers are able to collect more milk and sell livestock for higher prices (F. Ndeto, Personal Communication, March 31, 2009). Regrettably, Nthongoni had the highest number of respondents indicating that they watered their livestock at the sand dam and had the most contaminated sand dam site. It is therefore crucial that communities devise measures to reduce contamination while still benefitting from the increased and nearby water supply. Sand dams also indirectly impact livestock production. During drought the lack of fodder often means

pastoralists lose part of their herd. The improved water tables around sand dams enable communities to grow grasses which can be sustainably harvested and sold or used to feed livestock.

In addition to selling harvested grasses, the sand dams also create other income generating activities. Once a sand dam is mature community members can sustainably harvest the excess sand. This sand can be used in construction and in the making of bricks. During the focus group discussion in Kitunda village one participant described that before the sand dam there were few permanent buildings in the village but now there are many (Kitunda focus group participant, personal communication, March 16, 2009). The availability of water also enables seedling production not just of fruit trees but also for firewood and timber. Nurseries are often carried out as a group endeavour (F. Ndeto, Personal Communication, March 31, 2009).

Collective action

The extension of group activities directly attributed to the construction of the sand dam was difficult to establish. The sand dam committees in Muiu, Nthongoni and Kitunda village all claimed that their communities had started other initiatives after the sand dam because they now knew the power of uniting.

In both Muiu and Nthongoni, the committee understood that several smaller groups had started tree nurseries. In Keuntunda sub-location there was no further collective action. However, the sand dam committee claimed that the community realized the value of coming together and if there was another project they would unite even though they have no resources to start their own projects. The sand dam committee in Kitunda village had also undertaken several projects. These initiatives such as tree nurseries, road maintenance, bee keeping, etc, can at least partially be attributed to further training offered by SASOL and the Kitui Development Centre, which showed them the value of natural resources management and a diversified income. Remple et al (2005) found evidence of collective

action to be limited. However, 22 percent of household interviewed in his study reported an increase in group activities since the construction of their sand dam.

5.2.4 Impact on the surrounding environment

Sand dams improve catchment degradation by enabling vegetative growth. In order for sand dams to reach maturity and function at optimum efficiency, effective erosion control needs to be in place. In each sand dam location, communities were encouraged to develop terraces in their *shambas* and to plant napier grass along the banks in order to reduce erosion. The improved water availability decreases the time associated with fetching water, enabling communities to put these practices in place and increases the amount of stored water, facilitating vegetative growth.

The construction of a single sand dam can influence water levels to a distance of 350 m upstream and downstream (Quilis et al, 2009). The improved water table allows ecosystems to regenerate. Planted napier grass or other shrubs and trees along the natural river line contribute to stabilize the river banks, decreasing the amount of erosion occurring in the catchment. All four sand dam committees with completed sand dams noted that the area around the sand dam has more vegetation and is in general greener. One respondent from Muiu noted that “the area around the sand dam has really changed, the climate is better and more green than was before” (Muiu respondent, personal communication, March 03.2009).

Substantial regeneration of natural vegetation is evident where sand dams have been constructed. Maddrell and Brown (n.d) provide support of enhanced biodiversity through photographs taken before and after the construction of a sand dam (Figure 43).



Figure 43. Manzaa valley in 1984 (left) before the Excellent Development sand dam and in 2002 (right) after. (Source: Maddrell and Bown, n.d)

Sand dams have also been constructed in order to rehabilitate gullies and reduce erosion. Nissen-Petersen (2006) noted that sand dams were built in gullies to harvest sand and stop it from silting up Lake Victoria.

5.2.5 Cost- effective

Sand dam projects use a cost sharing approach. Communities are required to provide the labour and locally available materials such as sand, stones and water, while the project proponent supplies the technical support and supervision as well as the cement, ballasts, pipes and other necessary material. With the SASOL projects the community is also responsible for housing and providing food to the artisan. The cost sharing approach used improves the project viability by making it cost-effective and therefore accessible for rural communities, NGOs and governments with limited resources. The use of locally available materials and community labour reduces the cost of construction by approximately 44 percent.

The cost of an average SASOL sand dam is 5, 000 US dollars plus community contributions (Ersten and Hut, 2009; Lasage et al, 2008), which equates to an average cost of 5 – 10 US dollars per consumer. Mati (2005 – as quoted in Maddrell and Bown, n.d) noted that sand and subsurface dams are the cheapest water harvesting technique to implement compared to water tank which are ten times the cost.

5.2.6 Feasibility

The feasibility of sand dams as an option for decreasing vulnerability to water scarcity in rural ASAL communities in Kenya is evaluated based on affordability, achievability and whether or not the development options are climate proof.

As illustrated above the low cost and cost-sharing approach enables sand dam projects to be readily affordable to both NGOs or governments and the local communities. The achievability of the strategy is enhanced because it is culturally appropriate, as people in Kenya have been collecting water from ephemeral streams through scoopholes for centuries. There are however barriers and areas of concern regarding sand dam construction and maturation. In addition to problems of siltation and contamination listed above, each community must take into consideration labour requirements and land ownership.

Sand dams are labour intensive strategies. All of the sand dam committees agreed that the provision of labour was a challenge to their communities. Participants were obliged to collect bags filled with heavy stones and carry them back to the sand dam site, to search for water in order to mix cement and to dig the trench for the sand dam. Hunger was also a concern. Communities were working full days expending large amounts of energy but didn't have any food. In addition, the time spent working on the sand dam meant that participants were not completing their own household and agricultural chores which contributed to their lack of food. The committee in Nthongoni explained that they worked full days close to the raining season and therefore failed to plant. The Kathamba group noted that they lacked the proper tools to dig the trench. One participant clarified that they had to use their own tools but that they were old and would fall apart against the hard bedrock. Another participant from the Kathamba committee described that the stones they needed to collect were far away, and that the women had to walk 2 km in search of stones. In Keutunda sublocation, one participant noted that water scarcity caused them to have to walk 10 km to the earth dam in search of water to mix the

cement. All of the committees made it clear that community members that didn't come to the working days were a challenge.

Unlike many water supply infrastructures, sand dams are not extractive technologies. They contribute to water conservation and groundwater recharge which will lessen the impacts of climate change. In Kitui District, the annual runoff is expected to decrease by 1 and 34 percent in the November to March and April to October seasons, respectively, due to climate change (Aerts et al, 2007). While precipitation is expected to increase overall, the decrease in runoff is associated with the higher rate of potential evaporation due to the increase in average temperature by 3°C. As water held within a sand dam is not susceptible to evaporation these sources of water are predicted to become more important. Under climate change scenarios, Aerts et al (2007) found that there remained enough water to fill the current 500 sand dams located in Kitui district. The sand dams continued to collect runoff however the percentage of annual runoff changed dramatically. During the April to October season the percentage of annual runoff collected behind the dams changed from 3 percent in 1950s to 20 percent in 2100 (Aerts et al, 2007). While sand dams are still effective at collecting water, the higher percentage of runoff may cause conflict with downstream users.

5.3 Factors and processes contributing to or constraining successful implementation of sand dam development and adaptation strategies

Many technical considerations are key to the proper functioning of a sand dam. These considerations include placement, design and construction. However the successful construction and maturation of a sand dam and its use as a platform for other ventures is also fundamentally associated with community motivation and know-how. Community based projects can either be initiated by a community group or by an implementing body. Motivation is implicit in projects initiated by the communities and is evident by the fact that the community has organized, identified problems, decided on possible solutions and has begun looking for resources. In this scenario the community is

the driving force. In contrast, in all five case studies, the implementing body initiated the project. As such it was the responsibility of the project proponents to mobilize and motivate the communities as well as to ensure that the communities are equipped with the necessary knowledge. From the case studies there emerged different factors and processes that both enabled and constrained community motivation. These factors ultimately determined the success of the sand dam development project. These key factors include understanding of the technology, past experiences, beliefs and perceptions, ownership, community cohesion and spirit, participation, capacity building and training, and coordination, communication and follow-up. These are discussed in the following sections.

5.3.1 Understanding of the technology

“only those who did not understand the benefits and usefulness of the project did not participate, also that those who didn’t participate might have been far from the site and thought that the sand dam would not benefit them but they didn’t understand that it would benefit the community as a whole and would unite the community to do other activities and development in the village” (Nthongoni respondent, personal communication, March 25, 2009).

With the exception of basic knowledge such as that a sand dam would bring more water and that with more water they would be able to grow more vegetables, all the case study communities but one lacked a true understanding of the function of a mature sand dam and how to ensure a sand dam reaches maturity.

A common illustration of the lack of understanding was their belief that, if they continued to collect water from scoopholes, as opposed to the installed pipes or adjacent shallow wells then the sand dam wasn’t working. The Muiu sand dam committee explained that livestock were getting water from the sand dam area but that no water for domestic purposes were collected as water was not yet coming from the pipe. Water was not coming from the pipe as the dam in Muiu village had not reached maturity. As the pipe had never been fitted in the Nthongoni sand dam, the committee believed that even if rains came and filled the dam they would not be able to access the water for domestic consumption without it. In Keutunda sub-location, the community indicated that the sand dam was

not working because there was no water in the shallow well built by SASOL adjacent to the dam. However, even after the second failed rainy season the community was able to collect water from deep scoopholes in the vicinity of the sand dam, which previously would have been dry. The communities did not comprehend that the sand dam causes the water table in the local area to rise. Only the committee in Kitunda indicated their understanding of this by explaining that one of the intended benefits of the sand dam is that the surrounding area would become greener.

As noted earlier, drowning was mentioned as a potential hazard associated with sand dams. Upon further inquiry this suggested a misunderstanding of the technology. Several members in each community believed that the purpose of the dam was to block surface water resulting in a collected body of open water. They did not realize that this open body would only be associated with an immature sand dam. A mature sand dam should be filled to the height of the dam wall with sand minimizing the potential for drowning. This misconception will negatively impact sand dam maturation as community members will be more likely to practice sand harvesting close to the dam. The tendency of this misunderstanding by communities was also noted by Gaff (2005) who stated “communities did not recognize that the accumulation of sand in a streambed was just as important a piece of their realization of water security as their construction of a cement and stone barrier – that a streambed without sand was also a streambed without water”.

Furthermore, only Kitunda village was able to link erosion control, promoted within the project, as a requirement for a properly functioning and mature sand dam. The other communities, recognized practices that would control erosion such as building terraces and planting trees and napier grass. However, they felt that these strategies were implemented only as a means of improving agricultural production. This was especially evident with the three communities in Makueni district forming part of the Resilience pilot project. The structure of the project was such that all objectives and associated activities ran concurrently. The participants that received training on proper agricultural practices such as erosion control were not necessarily the same as those participating in the sand dam

construction hence there was little opportunity to link the natural resource management practices to essential for the maturation and effectiveness of the sand dam. Sand dam projects need to educate and show interrelatedness of all good practices in order to be successful.

5.3.2 Past experiences, perceptions and beliefs

Each community joins a new project with past experiences, beliefs, and perceptions, all of which will influence their motivation to complete the sand dam project. In Keutunda, the community had previously constructed a sand dam with another organization which according to SASOL never functioned (F.Kimwilu, personal communication, February 19, 2009). This affected the level of participation as some members felt that the previous project had failed them and that the technology, in general, didn't work. In contrast, others misunderstood the technology believing simply that sand dams take time to mature and collect water. This is true, however, the fact that this community has been waiting seven years to see ANY improvement means that they lacked an understanding of the technology and also lacked the means to take remedial action when the dam wasn't performing.

In order to form a composite of their beliefs and perceptions, households and sand dam committee members were asked to identify the main problems in their communities. Water shortages, lack of food and health were mentioned most frequently. Unfortunately, those interviewed did not always link sand dam projects as solving all three their most salient problems. The most frequently listed benefits of sand dams, both realized and expected, were improving water availability and proximity, and permitting vegetable gardens. Seldom mentioned were the health benefits achieved through the ability to wash more often and through cleaner water, nor the time saved by having nearby water sources. Few associated the saved time from walking long distances with time that could be spent in improving agricultural production or output from other enterprises.

Concerning beliefs, religion also played an important role in all of the case study communities. This was evidenced previously by the number of household respondents that indicated that God was the

main cause of the failed rains. This belief in an omnipotent God also influenced the people's faith or lack thereof in their own solutions to their identified problems. In every community with the exception of Muiu village, there were a few respondents that indicated that there was nothing to be done that only God could fix their problems. In each of the focus group discussions I was advised to begin the process with a prayer, I was also asked on several occasions during my research whether or not I was personally religious. The intent of this question was to establish whether or not I was to be trusted. Project leads or proponents need to recognize that religion can be an important point of entry or a barrier to the success of a sand dam project. Respect for and sensitivity to the religious beliefs of a community is crucial to gain credibility with the people.

Other perceptions influencing the success of sand dam projects are those relating to faith and dependence in governments and non-governmental institutions. Many felt as though solving the problems of water scarcity was the responsibility of the government, this impacted the community's motivation to complete their own projects. Institutions, especially government organizations, implementing sand dam projects need to ensure that it is not simply perceived as a government or non-governmental intervention but rather as a joint venture with the community. During the focus group discussions, the committees were asked what the driving force was behind the project and what their vision was; most responded simply that "they were told they would get water, if they provided the labour". They did not have a broader vested goal that they were trying to achieve. In fact, the Kitunda village sand dam committee clearly stated that it was SASOL's vision not theirs. Sand dam project proponents claim that this level of community empowerment is created through the labour and participation during the construction stage. However in contrast, in all the case study communities, the committees became inactive once the dam was built. It was evident, strictly from the sand dam project that, with the exception of Kitunda village, the communities had not realised their power or the potential of the project to act as a catalyst. Excellent Development co-founder Joshua Mukusya (personal communication, January 22, 2009) explained that in their projects they

organize exchange programs to overcome some of these concerns. At these exchanges community groups are able to come together and share their experiences. Those communities that are just beginning a project return from these meetings with a sense of strength realizing what they can achieve.

5.3.3 Ownership

Successful sand dams are those in which the committee has ownership over the dam and the surrounding areas. Ownership in this sense is comprised of several parts such as legal ownership, care and financial ownership, and feelings of ownership.

In most of the case study locations it appeared that the sand dam was built adjacent to private land. In Kenya, permits to water resources run with the land, it is therefore necessary that at the onset of a sand dam project, stakeholders need to clearly define ownership and rights of access. Failure to establish these rules and regulations might result in the community being denied access to the sand dam and therefore denied access the benefits. The committee should retain a signed memorandum of understanding between the landowner, the implementing institutions and the community that ensures that the committee and community may access the sand dam at all times. In addition, Remple et al (2005) noted the importance of outlining an exterior boundary along the banks necessary to ensure that the sand dam reaches maturity. These outer boundaries must also come under the agreement providing ownership to the community. The control of the outer boundary allows the committee to plant napier grass and protect the sand dam from siltation. Excellent Development further encourages the community groups to register as WRUA and to acquire legal permits and licences in relation to the water resources collected by the sand dam. It is only with the permit that groups can legally enforce rules and regulations such as who in the community can access the sand dam, how often households can access and how much water each can collect. Additionally, the permits allow the committee to determine the rules surrounding sand harvesting from the river bed thereby ensuring the sand dam is protected (J.Mukusya, personal communication, January 22, 2009).

Feelings of ownership and the uptake of responsibility are harder to attain and are not simply achieved through the signing of legal documents. When asked, who owns the sand dam, the large majority of respondents stated that the community owned the dam. It was obvious that this was the notion that had been told to them by the implementing institutions. Unfortunately, the responses weren't as unanimous when the communities were asked who was responsible for fixing/maintaining the dam and how they planned on maintaining/fixing the dam. Approximately half of the households in each community indicated that the local people were responsible, except for Kathamba where all the respondents believed that it was the local community's responsibility to repair the sand dam. The other half believed that it was either the responsibility of the implementing institutions or they didn't know. As for the committees, all of them had rules to ensure the dam was protected however none of them had plans on how to enforce these rules nor were the rules known by the majority of household respondents. In addition, all of the sand dam committees indicated that their first step when or if there was a problem with the sand dam would be to contact the project proponents. It is clear that proper training in project sustainability and management is fundamental to long term success of sand dam development projects. Additionally, none of the committees had developed or thought of ways in which they would be able to pay for any eventualities such as repairs or expansions if the river meandered. This lack of clear ownership and capacity absolved them of responsibility.

Many organisations missed the opportunity to build a sense of ownership in the communities by emphasizing the cost contribution of labour and locally available materials. A key enticement for sand dam development projects is the notion that the community contributes half and in some cases more to the cost of the project, through labour and the collection of locally available materials.

However, only two households interviewed (both from SASOL's projects) believed that the implementing institutions and the local community jointly funded the project. In fact, these two respondents were the only two who mentioned that the local community made any financial contribution at all. The large majority of households interviewed in Makueni indicated that they did

not know who funded the sand dam, while most of the respondents in Kitui stated that SASOL paid for the sand dam. Educating communities in cost analysis and budget planning could help build ownership not only by helping them realise the value of their work but also through involvement in more of the project planning.

5.3.4 Community cohesion and spirit

Trust, cohesion and spirit are all the idyllic characteristics presumed to be inherent in many rural African communities. I would like to prefix the following by stating that the communities were exceptionally welcoming, kind and generous with me and appeared to that way with each other. There were however several of the case study communities where conflicts and tensions existed.

For example, in Kitunda community, there were obvious tensions between the assistant chief and the sand dam committee and SASOL team. As far as the assistant chief was concerned the committee acted dishonestly promising community members that they would be paid for working on the sand dam project (D. Mutisya, personal communication, February 23, 2009). During the focus group discussion the committee explained that some community members believed this but that is was just a rumour. The committee furthered that the only exchange of money was from households that did not participate, who were fined either 50 Ksh or had to bring some food for the participants. The assistant chief also indicated that SASOL's communication with him was lacking and that he had not been briefed on any activities since they first approached him with the proposal. It needs to be recognized that the assistant chief is a significant bridge between the community the district government and wields a considerable amount of influence. Therefore, for the continual success of projects, the implementing body and the community should ensure that the local government remains informed.

Another example of a situation resulting in tension was seen in Keutunda sub-location. Two cements companies, Bamburi and Athi River Mining, were trying to secure mining rights to the local limestone deposits. As a result residents speculated that the local administration and others would

benefit, while the rest would simply be displaced from their homes. One bamburi employee stated that there are those who want it and those that don't and explained that there had been several attempts to sabotage bamburi survey equipment (Bamburi employee, personal communication, February 20, 2009). The focus on the limestone dispute and assumptions of relocation impacted the sand dam project as many felt that the project is irrelevant as community members would be relocated (F.Kimwilu, personal communication, February 19, 2009). Another indicator of this community's lack of cohesion and group mentality was the fact that almost half of the households interviewed were not a part of a single self-help group. While communities are not going to turn down free cement, organisation implementing sand dam projects need to take the time to determine which communities are committed.

The sand dam project in Nthongoni dealt with problems of community cohesion as well. Project documentation indicated that prior to the elections in 2007 community members began demanding payment for their work (Resilience Project, n.d.b). The perception was that the project had lots of money. The ALRMP explained that the purpose of the project was to benefit the entire community and this was why they needed to contribute to its success. In the end, only 18 members, in a community with 128 households, were convinced of the opportunity and completed the construction of the sand dam. Despite the fact that the sand dam was built, the project has left ill feelings throughout the community. Although a small number of naysayers were encouraged by the dam's completion, the majority remain sceptical. There were many criticisms real or perceived, relating to the honesty of the sand dam committee volunteers. Many respondents believed that the group had stolen and sold project cement and that they received payment for their labour. One household interviewed stated explicitly that "they would be happy to build another sand dam in the community but only if the original committee was not involved" (Nthongoni respondent, personal communication, March 06, 2009). In contrast, other community members indicated that they have been proven wrong and that if there was to be another project they would go and participate. The 18

volunteers, on the other hand, adamantly claim they did not receive payment and feels offended that the whole community waters their livestock at the sand dam without recognizing their significant labour contribution. The sand dam in Nthongoni village also has little chance of maturing, as the high numbers of livestock brought to the sand dam are causing severe erosion on the banks. Fostering proper community cohesion and participation at the on-set would likely have fostered a concerted effort to implement tasks to enable the dam to reach maturity.

Beyond pre-existing community cohesion and tension, initiating procedures can facilitate or oppose the development of a group mentality. Both implementing institutions in this study requested that the communities find potential sites for the sand dam and select a sand dam committee. The communities were advised to select sites that were accessible and would serve the largest amount of people. Being involved in the process of placement also contributed to community cohesion, as members felt as though they had had some input in the planning stage. All of the committee members from each case study location claimed to be democratically elected by their communities. While SASOL would advise communities as to the composition of the committees, suggesting that there should be an equal representation from people of different age groups, genders, education levels, religious beliefs and political party affiliations, they would not dictate the process (Ertzen et al, 2005). The households interviewed in each of the case study locations rendered multiple responses when asked of the existence of the sand dam committee and how the members were selected. From both the Kitui district locations, almost half of the respondents indicated that the committees were democratically elected, the remainder were unsure of the process, the committees existence, or believed that the village elders had chosen the members. The results were more distributed for the projects in Makueni district. In Muiu village, the largest percentage of people indicated that they were unsure how the committee was selected, followed by those who thought the committee was democratically elected and the remainder believed that the village elders or project proponents had appointed people. In Nthongoni the split was equal between those households not knowing how the committee was

selected to those households that believed the members were elected. In Kathamba the largest number of respondents felt as though there was no committee. The manner in which the sand dam committees are selected will influence the amount of trust that the community has in the committee and their general feelings of inclusion.

Organizations taking on any community based project need to be aware of the state of cohesion and trust between community members and the impact that certain exercises, if not executed with sensitivity, can have on breaking those connections. For the sand dam projects, proponents need to invest in participatory team building.

5.3.5 Participation

Participation is the cornerstone of sand dam development projects. Irrespective of the community benefits brought about by participation, the involvement of the people is necessary in order to keep the cost of the project low and viable to institutions. As there is a lot of work associated with the construction of the dam and the work is hard, requiring physical strength and stamina, it is essential that communities gain as many participants as possible in order to share the work. On average one sand dam constructed by SASOL required 604 workings days. This averaged among 30 community members still amounts to 20 full days of labour. Excellent Development has found that younger communities are often more successful with sand dam projects as they were less affected by the level of work involved (J.Mukusya, personal communication, January 22, 2009). It is therefore important that organizations ensure that younger community members are also motivated to participate.

Participation can be encouraged in several ways. In the case study communities, people were mobilized to take part in the project through community meetings where the benefits of sand dams were explained and by the village elders, who went door-to-door persuading members to participate. Other strategies commonly used were the use of fines and restrictions. All of the committees described that households in the community that did not participate were fined and individuals that

were late were also fined. Nevertheless, I found little evidence from the household questionnaires and speaking with community members that a fine in the form of money or food was ever collected.

Monitoring participation can be complicated. In many households the able bodied were needed in the *shambas* or had migrated in search of employment leaving the sick or elderly to look after the children. For committees it is difficult to determine which reasons for not participating are justifiable and for which households should be fined or restricted from accessing the completed dam.

There are also several barriers to people participating such as distance to project sites, time constraints and age or disabilities limiting the amount of work people can accomplish. In Muiu, many household respondents indicated that they did not participate because the dam was too far to benefit them. Subsequently, during the focus group discussion with the Muiu sand dam committee, the group described that they tried to engage these households by making clear “that the community must work together to build this one and then when build one close to them the whole community with assist them” (Focus group participant, Muiu village, April 7, 2009). As a group, we brainstormed other ideas that they could have tried and it was suggested to have a community vision. The vision would outline all the goals they had for their community and how these goals were to be accomplished. In this way the households that were more remote would feel as though the community was working towards a common objective.

For all of the households it was a struggle to participate throughout the dry season as food was scarce. This scarcity not only meant that low energy levels impacted the ability to do the work but also that their time was needed to search for food and water. In Kitunda and Nthongoni villages, the members participating in the construction all brought food and cooked together. However, it was suggested that if project institutions could factor in food-for-work programs, then the community would be able to build faster and more members would participate. As the dry season drew to an end, participation was also difficult as households needed to prepare their land for planting before the rains started. While sand dam committees were able to choose when the community worked, it was the organizations that

dictated the timeline. It is, therefore, essential for effective participation that project proponents are cognizant of the realities of work families need to complete in order to survive.

In general the case studies revealed that positive incentives and effective mobilization were better motivators than restrictions or fines which were perceived negatively and never enforced. Project proponents need to invest the time to ensure that communities are genuinely keen and able to complete the work necessary for the project to be successful.

The theory behind the cost sharing strategy is that an actively engaged community that donates their time and energy to the construction of the sand dam will innately develop ownership of the dam and be vested in its success. The provision of free labour for projects is not a new phenomenon in rural African communities, despite this, projects across the continent have not been maintained. Building ownership and ensuring sand dams reach maturity and work effectively will require community participation on more levels than simply providing labour for the construction. In this regard, both the Resilience pilot project and SASOL were slightly limited in that the organizations were only offering one strategy. While both institutions initiated the project through participatory approaches where the communities defined their problems, neither organization allowed the communities to develop their own plans to accomplish what they wanted to achieve. According to Excellent Development co-founder “success depends on freedom given to communities to make decisions, when freedom is given communities are more committed” (J. Mukusya, personal communication, January 22, 2009). During both the household questionnaires and the focus group discussions it was apparent that community members saw the implementing bodies as leading and directing the project and not themselves. The majority of households interviewed in Makueni district stated that the community had very little to do with the initiating or planning stage of the project. In contrast, the majority of respondents in Kitui district believed the community played a large role in the planning, which included scheduling working days, selecting the site, and electing the committee. The more levels the community is allowed and enabled to participate on encourages them and builds capacity.

5.3.6 Capacity building and training

Building a community's capacity to effectively maintain, manage and ensure their sand dam reaches maturity is essential to a successful and sustainable project. In each community there was evidence of past projects that were no longer functioning. In Kathamba village, there was a sand dam that wasn't maximally blocking the river's base flow as the river had meandered in recent years. While the community could have maintained their investment by extending the dam without too much trouble, the community lacked the wherewithal to mitigate these occurrences. Instead they explained that they were waiting for someone to come and fix the dam.

All of the sand dam committees claimed that they were promised training sessions regarding dam maintenance, however only the communities in Kitui district received the promised sessions. SASOL offers each community that builds a dam a series of three training courses. These trainings are fundamental to empowering the community and providing them with the tools to guarantee that the greatest results are realized from their sand dam development project. The first training session taught the communities about proper natural resources management. The groups were told about the interactions between air, soil, water, and vegetation and the necessity to take care of each element. They were also shown how to harvest water and manage runoff, for example by building terraces and capturing road runoff. The second session outlined proper project management. The goals of this course were to ensure project sustainability by training the community to use water wisely and to generate income through horticulture, bee keeping and pottery (F. Ndeto, Personal Communication, March 31, 2009). The third and final session focused on participatory hygiene and sanitation. This course taught the community to be proactive about health and well-being by being aware of and mitigating disease transmission. They are educated on the prevention of malaria, the proper disposal of waste and how to implement personal hygiene.

Each session occurred over the course of a week and was offered to ten members of the community. Those who are trained by SASOL are then expected to return to the community and train ten other

members. In communicating with the two communities under SASOL's guidance there was evidence that the delivery of the training sessions was less than ideal. In both communities cattle could be seen to access water in the river bed in places upstream from where residents collected their domestic water. The connection that livestock were polluting the water through urination and defecation that would then be collected by the community downstream was not realized. Gaff (2005) also noted that the sessions were dense and packed with information and that the participants most of which had had little formal education were "left to pick and choose among the varying lessons that had been handed to them over the course of training, latched onto one or two that seemed most interesting and carried that, and that alone, back to their communities". Ideally, the lessons should be more spread out over time allowing the students to absorb the material and have opportunities to ask questions.

While, the Resilience project also passed on similar information to the communities through multiple strategies, these training were not linked to the sand dam. Instead the sand dam was simply viewed as a concrete structure which when built would supply more water. It has been clearly established that in order for a sand dam to be successful the community must be engaged in much more than the construction.

Jucinda Nakiyu from the Kenyan Water Resources Management Authority stated in an interview that "training is crucial it is the key issue. It is this aspect that takes the most time. We have to sit down and decide how they want their catchment to be managed so that their water sources remain viable and healthy. If the sand dams are to have an effect the community needs to learn how to manage and have to be effective managers. How the sand dam will be managed needs to be written in from the very initial proposal, don't build the dam without the community being involved and the management being written" (J. Nakiyu, Personal Communication, April 15, 2009).

5.3.7 Communication, promises and follow-up

Organizations implementing development projects need to recognize that their role extends far beyond the provision of material resources. Although delivering on the resources promises is essential, the manner, timeliness, and level of communication and follow-up also have significant impacts of project success.

Both the Resilience project and SASOL missed key opportunities to encourage and facilitate community ownership through their lack of follow-up. SASOL's mandate is to build as many dams as possible in Kitui District and therefore directs its resources to construction as opposed to follow-up and the ensuing project maintenance (Gaff, 2005). However, the importance of maintaining the connection with the community can be shown by contrasting the two case study communities that constructed their sand dam with SASOL. Kitunda village is highly organized and has completed several other development projects which they claim were catalyzed by SASOL and the sand dam. The sand dam committee in Kitunda explained that they now come together as a community and look at their problems and discuss solutions. Currently, the community is divided into four subgroups, with each group tackling a particular problem or livelihood activity such as tree planting and the creation of a nursery; poultry keeping; goat keeping; and fruit tree planting. In addition, the community has also extended its enterprises into bee keeping and sunflower production, which provides them with edible oil. They have also decided to re-unite as a group in order to rehabilitate the road network in their village (Kwa Ndunda focus group discussion, personal communication, March 16, 2009). In the 14 years, since Kitunda village's sand dam was completed SASOL has never left the community. As the village is close to Kitui town and SASOL's headquarters it has often been used as a demonstration sand dam when funders and other interested proponents wish to see one of SASOL's projects. SASOL has also formed key partnerships which influence the communities close to Kitui town. Through an agreement with a university in the Netherlands, students are able to come to Kenya and complete research projects at this site. This often leads SASOL back to Kitunda village, where the

community is asked to support the students and in turn the community benefits from being encouraged in their projects. Another partnership and fortunate alliance for Kitunda village is the partnership SASOL has with the KDC. SASOL engaged the KDC to run their three training programs in Kitunda village. Subsequently the KDC completed other development projects with the community. In contrast, Keuntunda has not benefitted from any of these partnerships or the strong presence of SASOL.

The level of rapport and communication communities have with project proponents influences their pride, confidence and ability to maintain their projects. The majority of households interviewed in Kitui district knew that it was SASOL that had completed the project and neither sand dam committee stated that there were any communication problems. In addition, both committees could easily identify ways they could contact SASOL if needed. Unfortunately, the same cannot be said for the projects in Makeuni districts. The majority of households interviewed could not identify any of the proponents involved in the project. There were those who believed it was an NGO and only one respondent believed it was the Arid and Semi-arid lands and another the agricultural ministry. The Resilience pilot project was a convoluted, multi-stakeholder project involving researchers from the University of Nairobi with the Centre for Science and Technology Innovations (CSTI), the Arid Lands Resource Management Project (ALRMP) and several other line ministries, such as the Ministry of Water and Irrigation, Ministry of gender and social development and the Ministry of agriculture.

The many partners as well as the several strategies being implemented concurrently and involving different groups of community members created confusion. Few households recognized the sand dam as part of a larger project aiming to reduce the impacts of drought. All the sand dam committee members, however, were able to connect the sand dam project to the larger Resilience project and could identify several contacts. Despite this, the three committees expressed frustration and fears with regards to the project. The pilot project was meant to be 3 years ending in February 2009, the focus

group discussions were held in April 2009 and none of the committees were aware of whether or not the project had ended. The committee in Muiu stated that the last time they were in contact with the ALRMP was in August 2008. Officials from the pilot project had in fact been in contact with the community subsequent to this date, however, with another subsection of the project, thereby demonstrating this disconnect between the various areas of the pilot project. This multi-faceted project design coupled with lack of communication demonstrated how the pilot project missed vital ways of improving community cohesion and organization. The sand dam committees in all three communities in Makueni district felt as though the project had broken promises made to them and just disappeared. In Muiu, the committee was waiting as they were told the sand dam would be raised over time. In Nthongoni, the sand dam was never completed and in Kathamba the community dug the trench for their sand dam three times and still had not had cement delivered. Multi-partner initiatives need to be diligent in communication with the communities and need to have an ongoing presence in order to succeed.

Beyond the project leader/community relationships, there were also communication breakdowns and coordination problems between all the different sectors implementing the project. The project was being overseen by the ALRMP from the district headquarters in Wote but the actual activities were generally being implemented by the line ministries. In regard to the sand dam project, there were misunderstandings in terms of who was responsible for ordering the materials, arranging for them to be brought to the community and knowing who was keeping it (F. Ndeto, Personal Communication, March 31, 2009). There were also confusions as to who was responsible for supervising, training the community and signing off on the completed dam. Staff resources and transportation were other limiting factors in maintaining contact with the communities (M. Kamwanza, Personal Communication, March 26, 2009; F. Ndeto, Personal Communication, March 31, 2009). Another concern which was out of the control of the pilot project was the division of the district headquarters

in the middle of the project. This resulted in the ALRMP office being located in Wote, Makueni District, while the other line ministries were located in Mbumbuni, Mbooni District.

While projects are limited by funding cycles and resources, even short follow-up sessions where training is enforced and the community is encouraged in their progress are essential. In addition, return visits force the sand dam committees to reconnect. Jucinda Nakiyu, Water Resource Management Authority, explains that when they work with WRUA they plan on being involved with them for 10 years. It is only in 10 years that the WRMA believe that the groups will be stable and self-sufficient enough to be left alone (J. Nakiyu, Personal Communication, April 15, 2009). The Resilience project did take this into consideration and while the pilot project is 3 years the partnership with the ALRMP was meant to facilitate as an ongoing resource for the communities. In contrast SASOL's effort to build sand dams and complete the training in 6 months does not appear to be sufficient to endorse successful sand dam development projects.

6. Conclusion

As an adaptation strategy with the potential of lessening community vulnerability to water scarcity, sand dam development projects have been shown to be appropriate. In contrast, to other water supply infrastructure, a sand dam adds value to the system by harvesting water that otherwise would have been lost downstream. In addition, the water is protected from high evaporation rates and cleaned through natural filtration process. The cost-sharing approach ensures community involvement and provides an attainable project for many governmental and non-governmental organizations working in rural Africa. The benefits of a sand dam also reach beyond the provision of water. The reduced distance to a water source that remains throughout the dry season, provides households with more time to spend on other income generating activities. Economic standing of the community also

increases as livestock are healthier, vegetables can be grown and alternative livelihoods can be established.

While these benefits can be realized, it is evident from the case study communities that a sand dam development project requires much more than simply building a concrete structure across an ephemeral stream. The dam itself is only the beginning of the project, however too often, the project proponents fail to take into consideration the factors necessary to ensure that a 'dam' becomes a 'sand dam'. Participation and capacity building are the keys to success. The experiences from the case study communities illustrate that there are many underlying reasons affecting a community's willingness to participate. Effective projects need to take the time to develop community cohesion and drive in order to successfully complete the sand dam. The construction phase, which albeit requires hard work, is the easy part for the communities who are used to following directives. Ensuring that a sand dam reaches maturity and remains viable is highly unlikely without proponents investing in training and capacity building. Training and capacity building, however, requires a large time and resource investment which is often beyond the scope of an organizations funding cycle. A solution, which was illustrated in the Kitunda community, is partnership building. If organizations building sand dams partner with another that would facilitate training on natural resources management, hygiene, project management and building capacity for alternate livelihoods, communities would experience maximum benefit. The length of time that communities are encouraged and supported will be doubled. In addition, in times of need the contacts and social resources that communities can draw on would have increased through the multiple partnerships.

7. References

- Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K., Pulhin, J., Pulwarty, R., Smit, B., and Takahashi, K. (2007). *Assessment of adaptation practices, options, constraints and capacity*. In Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (Eds), *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press
- Adger, W.N., Brooks, S., Kelly, M., Bentham, G., Agnew, M., and Eriksen, S. (2004). *New indicators of vulnerability and adaptive capacity* [Technical Report No. 7]. Tyndall Centre for Climate Change Research.
- Adger, W.N., Huq, S., Brown, K., Conway, D., and Hulme, M. (2003). Adaptation to climate change in the developing world. *Progress in Development Studies* 3(3): 179-195
- Adger, W.N. and Kelly, P.M. (1999). Social Vulnerability to Climate Change and the Architecture of Entitlements. *Mitigation and Adaptation Strategies for Global Change* 4(3-4): 253-256
- Aerts, J., Lasage, R., Beets, W., de Moel, H., Mutiso, G., Mutiso, S., and de Vries, A. (2007, August). Robustness of Sand Storage Dams under Climate Change. *Vadose Zone Journal* 6(3).
- Allan, T. (2003). *IWRM/IWRAM: a new sanctioned discourse?* [Discussion Paper No. 58]. London: Water issues study group, University of London.
- Anderies, J., Janssen, M., & Walker, B. (2002). Grazing management, resilience and the dynamics of a fire driven rangeland. *Ecosystems* 5: 23-44.
- Anderies, J., Walker, B.H., and Kinzig, A.P. (2006). Fifteen Weddings and a Funeral: Case Studies and Resilience-based Management. *Ecology and Society* 11(1): 21
- Arab Water Council. (2009). *Vulnerability of arid and semi-arid regions to climate change – impacts and adaptive strategies*. Perspective on water and climate change adaptation, WWC, CPWC, IUCN and IWA.
- Arid Lands Resource Management Project (ALRMP). (n.d). Adaptation to climate change project – Sakia pilot project – Environmental management plans for the proposed construction of sand dams and shallow wells in Sakai community of Kisau division Makueni District. Arid Lands Resource Management Project II.
- Arid Lands Resource Management Project (ALRMP). (October 2007). Report on the trip to Makueni from 8th to 11th August 2001 for Sand dams and wells construction – Feasibility Assessment. Arid Lands Resource Management Project II.
- Arid Lands Resource Management Project (ALRMP). (2009). Arid Lands Resource Management Project II. <<http://www.aridland.go.ke/index.php>> (accessed 15.01.09)

- Associated Press. (2009, January 9). Kenya: 10 million risk hunger after harvests fail. *Associated Press*. <<http://www.msnbc.msn.com/id/28579290>> (accessed 22.01.09)
- Barsby, J. (2008). *Culture Smart Kenya*. London: Bravo Ltd.
- Bates, B., Kundzewicz, Z.W., Wu, S., and Palutikof, J. (Eds). (2008). *Climate Change and Water*. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.
- Beekman, H.E., Odada, E., Afouda, A., Abu-Zeid, K., Sayman, I.S., Opere, A., Oyebande, L., Kane, A., Kulindwa, K. And Hughes, S. (2005). *Vulnerability of Water Resources to Environmental Change in Africa: River Basin Approach* [Early Warning and Assessment Report]. UNEP and Pan Africa START Secretariat (PASS).
- Berkes, F. (2007). Understanding uncertainty and reducing vulnerability: lessons from resilience thinking. *Natural Hazards* 41: 283-295.
- Bingeman, K., Berkes, F., and Gardner, J. (2004). Institutional response to development pressures: Resilience of social-ecological systems in Himachal Pradesh, India. *International Journal of Sustainable Development and World Ecology* 11(1): 99-115
- Biswas, A.K. (2004). Integrated Water Resources Management: A Reassessment. *Water International* 29 (2): 248-256
- Blaikie, P., Cannon, T., Davis, I. and Wisner, B. (1994). *At Risk: Natural Hazards, Peoples Vulnerability and Disasters*. London: Routledge.
- Borst, L and de Haas, S.A. (2006). *Hydrology of sand storage dams. A case study in the Kiindu catchment, Kitui District, Kenya* [Master Thesis Hydrogeology]. Amsterdam: Vrije Universiteit.
- Burton, I., Smith, J.B., and Lenhart, S. (1998). *Adaptation to Climate Change: Theory and Assessment*. In Feenstra, J.F., Burton, I., Smith, J.B., and Tol, R.S.J. (Eds), *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Amsterdam: Institute for Environmental Studies, Vrije University and Nairobi: Atmosphere Unit, UNEP.
- Cannon, T., Twigg, J. And Rowell, J. (2004). *Social Vulnerability, Sustainable Livelihoods and Disasters*. London: DFID.
- Cap-Net. (n.d). *IWRM a Tool for Adaptation to Climate Change* [Training Manual]. South Africa: Capacity Building for Integrated Water Resources Management, UNDP. <www.cap-net.org> (accessed 29.10.09).
- Cap-Net. (2008, June). *Integrated Water Resources Management for River Basin Organizations* [Training Manual and Operational Guide]. South Africa: Capacity Building for Integrated Water Resources Management, UNDP. <www.cap-net.org> (accessed 02.11.08).
- Clarke, R (Ed). (1999). *Global Environment Outlook 2000*. London: Earthscan Publications.
- Conway, G. (2009, October). *The science of climate change in Africa: impacts and adaptation* [Discussion paper No 1]. Grantham Institute for Climate Change, Imperial College, London, UK.

- Cutter, S.L. (1996). Vulnerability to environmental hazards. *Progress in Human Geography* 20(4): 529-539
- Darkoh, M. B. K. (1993). Desertification: the scourge of Africa. *Tiempo* 8: 320-331.
<<http://www.cru.uea.ac.uk/cru/tiempo/issue08/desert.htm>> (accessed 09.07.09)
- Davies, S. (1993). Are coping strategies a cope out? *IDS Bulletin* 24(4): 60-72
- De Loë, R., Kreutzwiser, R., and Moraru, L. (2001). Adaptation options for the near term: climate change and the Canadian water sector. *Global Environmental Change* 11: 231-245.
- Economic Commission for Africa (ECA). (2006). *Water in Africa – Management Options to Enhance Survival and Growth*. NEPAD <<http://www.uneca.org/awich/nepadwater.pdf>> (accessed 12.11.08)
- Eriksen, S.H., Brown, K., and Kelly, P.M. (2005). The dynamics of vulnerability: locating coping strategies in Kenya and Tanzania. *The Geographic Journal* 171(4): 287-305
- Eriksen, S.H. and Kelly, P.M. (2007). Developing credible vulnerability indicators for climate adaptation policy assessment. *Mitigation and Adaptation Strategies for Global Change* 12: 495-524
- Eriksen, S., O'Brien, K., and Rosentrater, L. (2008). *Climate Change in Eastern and Southern Africa: Impacts, Vulnerability and Adaptation*. Oslo, Norway: Global Environmental Change and Human Security Project.
- Ertsen, M., Biesbrouck, B., Postma, L., van Westerop, M. (2005). *Community organisation and participatory design of sand-storage dams in Kenya*. In: Goessling, T., Jansen, R.J.G., Oerlemans, L.A.G. (eds), *Coalitions and Collisions*. Wolf Publishers, Nijmegen, pg 175-185.
- Excellent Development (2007). *Excellent Development 2006-07 Annual Review*. England: Excellent Development. <www.excellentdevelopment.com> (accessed 17.04.09)
- Excellent Development (2009). *Excellent Development 2008-09 Annual Review*. England: Excellent Development. <www.excellentdevelopment.com> (accessed 01.11.09)
- Falkenmark, M., Berntell, A., Jägerskog, A., Lundqvist, J., Matz, M., and Tropp, H. (2007). *On the verge of a new water scarcity: A call for good governance and human ingenuity* [SIWI Policy Brief]. Stockholm International Water Institute.
- Falkenmark, M., Fox, P., Persson, G., and Rockstrom, J. (2001). *Water harvesting for upgrading of rainfed agriculture. Problem analysis and research needs*. Stockholm International Water Institute.
<http://www.siwi.org/documents/Resources/Reports/Report11_Water_Harvesting_for_Upgrading_Rainfed_Agriculture_2001.pdf> (accessed 05.06.09)
- Feenstra, J.F., Burton, I., Smith, J.B., and Tol, R.S.J. (Eds). (1998). *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies*. Amsterdam: Institute for Environmental Studies, Vrije University and Nairobi: Atmosphere Unit, UNEP.
- Few, R., Osbahr, H., Bouwer, L.M., Viner, D., and Sperling, F. (2006). *Linking Climate Change Adaptation and Disaster Risk Management for Sustainable Poverty Reduction*. Synthesis Report,

Study carried out for the Vulnerability and Adaptation Resource Group (VARG).

- Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C., Walker, B., et al. (2002). *Resilience and Sustainable Development: Building Adapting Capacity in a World of Transformation*. Stockholm: Swedish Environmental Advisory Council.
- Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., et al. (2004). Regimes shifts, resilience and biodiversity in ecosystem management. *Annual Review in Ecology, Evolution and Systematics* 35: 557-581
- Ford, J., Smit, B. and Wandel, J. (2006). Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Nunavut. *Global Environmental Change* 16:145-160
- Gaff, P. (2005). *An Assessment of the Strengths and Weakness of the Organizational and Environmental Aspects of the Sand Dam Paradigm* [Project Documentation]. Washington, U.S.A: American University.
- Gichuki, F.N. (2000). *Makunei District Profile: Water Management, 1989-1998* [Working Paper 3]. Somerset: Drylands Research
- Gichuki, F.N., Mbogoh, S., Tiffen, M. and Mortimore, M. (2000). *Makunei District Profile: Synthesis* [Working Paper 11]. Somerset: Drylands Research
- Global Humanitarian Forum. (2009). *Human Impact Report - Climate Change: the anatomy of a silent crisis*. Global Humanitarian Forum, Geneva.
<www.ghf-ge.org/programmes/human_impact_report/index.cfm> (accessed 06.06.09)
- Government of Kenya (GoK). (n.d.). *Adaptation to Climate Change Project – Sakai Pilot Project: Environmental Management Plans for the Proposed Construction of Sand Dams and Shallow Wells in Sakai Community of Kisau Division, Makueni District*. Wote, Kenya.
- Government of Kenya (GoK). (2009, February). *Draft National Policy For Disaster Management in Kenya*. Nairobi, Kenya
- Government of Kenya (GoK). (2009a, November). *National Policy For the Sustainable Development of Arid and Semi Arid Lands of Kenya*. Nairobi, Kenya
- Government of Kenya (GoK). (2009, June). *Kenya Food Security Update*. Nairobi: Kenya Food Security Network
- Government of Kenya (GoK). (2005). *Poverty Reduction Strategy Paper: The Economic Recovery Strategy for Wealth and Employment Creation (2003-2007)*. Nairobi, Kenya.
- Grey, D. And Sadoff, C.W. (2007). Sink or Swim? Water Security for Growth and Development. *Water Policy* 9(6): 545-571
- Grothmann, T. And Patt, A. (2005). Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Global Environmental Change* 15(3): 199-213

- Guba, E.G., and Lincoln, Y.S. (1994). *Competing Paradigms in Qualitative Research*. In N.K. Denzin and Lincoln, Y.S (Eds), *Handbook of Qualitative Research*. California: Sage Publications Inc.
- Gunderson, L. (2000). Ecological Resilience in Theory and Application. *Annual Review in Ecology and Systematics* 31 (1): 425-439
- GWP. (2000). *Integrated Water Resources Management* [TAC Background Paper No.4]. Stockholm, Sweden: Global Water Partnership.
- GWP. (2009). *Investing in infrastructure: The value of an IWRM approach* [Policy Brief No. 7]. Stockholm, Sweden: Global Water Partnership.
- Heathcote, I. (1998). *Integrated Watershed Management: Principles and Practices*. New York: John Wiley and Sons, Inc.
- Holling, C.S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics* 4: 1-23
- Holling, C.S. and Gunderson, L.H. (2001). *Resilience and Adaptive Cycles*. In L.H. Gunderson. and C.S. Holling (Eds). *Panarchy: understanding transformations in human and natural systems*. Island Press, Washington, D.C.
- Hulme, M., Doherty, R., Ngara, T., New, M.G., and Lister, D. (2001). African Climate Change: 1900 – 2100. *Climate Research* 17: 145-168.
- Increasing Community Resilience to Drought in Makueni District (Resilience Project). (n.d.). *Overview of Key Issues and Challenges in the Project Area* [Project Documentation]. Wote, Kenya: ALRMP Office.
- Increasing Community Resilience to Drought in Makueni District (Resilience Project). (n.d.a). *Makueni Household Survey Report* [Project Documentation]. Wote, Kenya: ALRMP Office
- Increasing Community Resilience to Drought in Makueni District (Resilience Project). (n.d.b). *Notes from ACCESA – Kenya Project Team meeting (October 14, 2008)* [Project Documentation]. Wote, Kenya: ALRMP Office.
- International Federation of Red Cross (IFRC). (1996). *Vulnerability and Capacity Assessments* [Toolbox]. Geneva: IFRC.
- International Institute for Sustainable Development (IISD). (2009). *Arid and semi-arid lands: Characteristics and importance*. <<http://www.iisd.org/casl/ASALProjectDetails/ASAL.htm>> (accessed 28.09.09).
- International Institute for Sustainable Development (IISD). (2007, 13-15 February). *Integrating Vulnerability and Adaptation to Climate Change into Sustainable Development Policy Planning and Implementation in Eastern and Southern Africa* [Regional Team Meeting Proceedings]. Nairobi, Kenya.
- IPCC. (2001). *Climate Change 2001: Impacts, Adaptation and Vulnerability. Contributions of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate*

- Change*. Cambridge, UK: Cambridge University Press.
- IPCC. (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contributions of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., and Hanson, C.E. (Eds). Cambridge, UK: Cambridge University Press.
- Isika, M., Mutiso, G-C.M., and Muyanga, M. (n.d.a). *Kitui Sand Dams and Food Security* [Project Documentation]. Sahelian Solutions: Kitui, Kenya.
- Isika, M., Mutiso, G-C.M., and Muyanga, M. (n.d.). *Kyangunga: the pushed become the pusher* [Project Documentation]. Sahelian Solutions: Kitui, Kenya.
- Johns Hopkins (1998, September). *Solutions for a Water-Short World* [Population Report. Vol. XXVI, No. 1]. Baltimore, Maryland, United States: Johns Hopkins Population Information Program. <<http://www.jhuccp.org/popreport/ml4sum.stm>>
- Jonker, L. (2007). Integrated water resources management: The theory-praxis-nexus, a South African perspective. *Physics and Chemistry of the Earth* 32: 1257-1263
- Kay, J.J., Reiger, H.A., Boyle, M., and Francis, G. (1999). An ecosystem approach for sustainability: addressing the challenges of complexity. *Futures* 31: 721-742
- Kelly, P.M., and Adger, W.N. (2000). Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation. *Climatic Change* 47: 325-352.
- Kiteme, B., Liniger, H., Notter, B., Wiesmann, U., and Kohler, T. (n.d). *Dimensions of Global Change in African Mountains: The Example of Mount Kenya*. International Human Dimensions Programme on Global Environmental Change. Bonn, Germany
<<http://www.ihdp.unu.edu/article/596>> (accessed 16.01.10).
- Kull, D. (2006). Connections between recent water level drops in Lake Victoria, Dam operations and drought. <<http://www.internationalrivers.org/files/060208vic.pdf>> (accessed 04.01.10)
- Lake Chad Basin Commission (LCBC). (2008, December). *To Save Lake Chad* [Background Paper]. Lake Chad Basin Commission & Water for Agriculture and Energy in Africa. Sirte, Libyan Arab Jamahiriya.
- Lambert, H.E. (1947a). Land tenure among the Akamba (Part I). *African Studies* (Johannesburg) 6(3): 131-147
- Lambert, H.E. (1947b). Land tenure among the Akamba (Part II). *African Studies* (Johannesburg) 6(4):157-175
- Lasage, R., Aerts, J., Mutiso, G-C.M., and de Vries, A. (2008). Potential for community based adaptation to drought: Sand dams in Kitui, Kenya. *Physics and Chemistry of the Earth* 33: 67-73.
- Lobe, K (Ed.). (2008). *Pathways to Resilience: Smallholder Farmers and the Future of Agriculture*. Canadian Food Security Policy Group Discussion Paper. <http://www.ccic.ca/e/003/food.shtml> (accessed 01.11.09)

- Luckham, R., Ahmed, I., Muggah, R., and White, S. (2001). Conflict and poverty in Sub-Saharan Africa: an assessment of the issues and evidence. *IDS discussion paper* 128: 1-67
- Maddrell, S. And Bown, S. (n.d). *Sand dams: Africa's answer to climate change?* [Project documentation]. Excellent Development, UK.
- Magrath, J. (2006). *Africa: Up in Smoke 2*. London: New Economics Foundation and International Institute for Environment and Development.
<<http://www.actionaid.org/assets/pdf/Africa%20Up%20In%20Smoke%202.pdf>> (accessed 05.05.09)
- Mathenge, O. (2009, July 13). All constituencies now turned into districts. *Daily Nation*, Nairobi.
- Mati, B. (2005). *Overview of water and soil nutrient management under smallholder rain-fed agriculture in East Africa* [Working paper 105]. International Water Management Institute.
- Manzi, H.K. (2005, September). *Kitui Sand Dam Socio-Economic Impacts and Outcomes from Changes in Agriculture Practices and Production* [Project Documentation]. Egerton University, Faculty of Agriculture.
- Mbuvi, D. (2006, August 28). *Implementation of Interventions on Adaptation to Climate Change in Kenya* [PowerPoint]. Arid Lands Resource Management Project, Makueni, Kenya.
- Medema, W. and Jeffrey, P. (2005). *IWRM and Adaptive Management: Synergy or Conflict?* [NeWater Working Paper No.7]. Germany: NeWater project. <www.newater.info> (accessed 01.10.08)
- Merrey, D.J. (2008). Is normative integrated water resources management implementable? Charting a practical course with lessons from Southern Africa. *Physics and Chemistry of the Earth* 33: 899-905
- Ministry of Planning and National Development (2002). *Makueni District Development Plan 2002 – 2008*. GoK.
- Ministry of Planning and National Development (2002a). *Kitui District Development Plan 2002 – 2008*. GoK.
- Ministry of State for Planning, National Development and Vision 2030 (2008a). *Makueni District Development Plan 2008 – 2012*. GoK.
- Ministry of State for Planning, National Development and Vision 2030 (2008b). *Mbooni District Development Plan 2008 – 2012*. GoK.
- Moberg, F., and Galaz, V. (2005). *Resilience: Going from Conventional to Adaptive Freshwater Management for Human and Ecosystem Compatibility* [Policy Brief No. 3]. Sweden: SIWI
- Moench, M., & Dixit, A. (2004). *Adaptive Capacity and Livelihood Resilience: Adaptive Strategies for Responding to Floods and Droughts in South Asia*. Nepal: Institute for Social and Environmental Transition.
- Munywoki, J.M., Kitema, M.I., Munguti, J.M. and Mutiso, S. (2004). *Kitui Sand Dams: Construction*

- and Operation* [Project Documentation]. Kitui, Kenya: SASOL Foundation
- Mutaki, V. (2009, January 15). Early Warning System [Monthly Report]. Drought Monitoring Office, Makueni. GoK
- Mutaki, V. (2008, September 14). Early Warning System [Monthly Report]. Drought Monitoring Office, Makueni. GoK
- Mutiso, S.M. (n.d.). *Sand dams: A catchment groundwater storage approach in arid and semi-arid lands* [Project Documentation]. Kitui, Kenya: SASOL Foundation.
- Mutiso, S.M. and Mutiso, G-C.M. (n.d.). *Kitui Sand Dams: A Development Paradigm* [Project Documentation]. Kitui, Kenya: SASOL Foundation.
- Mutua, F. (n.d.). *Creating a GIS database for mapping climate change, vulnerability and adaptability: Case study – Sakai sublocation, Makueni District, Kenya* [Project Documentation]. Wote, Kenya: ALRMP Office
- Nicol, A., and Kaur, N. (2009, March). Adapting to climate change in the water sector [Background Note]. UK: Overseas Development Institute.
- Nilsson, A. (1988). *Groundwater Dams for Small-Scale Water Supply*. Intermediate Technology Publications, London.
- Nissen-Petersen, E. (2006). *Water from Dry Riverbeds: How dry and sandy riverbeds can be turned into water sources by hand-dug wells, subsurface dams, weirs and sand dams*. Kenya: ASAL Consultants Ltd for the Danish International Development Agency (DANIDA).
- Nyaga, C.W. (2005, September). *The process of sand dam construction and the effects on food security, health, gender roles and community development* [SASOL Project Documentation]. Machakos, Kenya: Community Nutrition Action Network
- Olago, D. (2007). *Water Harvesting and Mining* [Powerpoint Project Documentation]. Nairobi, Kenya: University of Nairobi, Department of Geology
- Opondo, M. (n.d.). *Increasing Community Resilience to Drought in Makueni District in Kenya* [PowerPoint]. Department of Geography and Environmental Studies, University of Nairobi.
- Opondo, M. (2008, march). *Integrating Socio-Economic Information and Community Capacity building to respond to Drought* [PowerPoint – Resilience Project Documentation]. Department of Geography and Environmental Studies, University of Nairobi.
- Oweis, T., Prinz, D., and Hachum, A. (2001). *Water harvesting. Indigenous knowledge for the future of drier environments*. International Centre for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria.
- Oxfam International. (2006, May). *Delivering the agenda* [Briefing paper No 88]. Oxfam International, United Kingdom.
- Parry, J-E. (2008). *Preparing for Climate Change in Kenya: Early Outcomes of the Project “Increasing Community Resilience to Drought in Makueni District”*. International Institute for

- Sustainable Development (IISD), Manitoba, Canada.
- Quilis, R., Hoogmoed, M., Ertsen, M., Foppen, J.W., Hut, R., de Vries, A. (2009). Measuring and modeling hydrological processes of sand-storage dams on different spatial scales. *Physics and Chemistry of the Earth* 34: 289-298
- RAIN Foundation & Acacia Water. (2007). *A practical guide to sand dam implementation: water supply through local structures as adaptation to climate change*. Amsterdam, the Netherlands: RAIN Foundation.
- Remple, H., Nyaga, C.W., Manzi, H.K., and Gaff, P. (2005, December). *Water in the Sand: An Evaluation of SASOL's Kitui Sand Dams Project* [Project Documentation]. Kitui and Nairobi: SASOL Foundation.
- Reynolds, C. (2005, September). Low Water Levels Observed on Lake Victoria. Report published on the Web site for the Production Estimates and Crop Assessment Division of the USDA Foreign Agricultural Service. <<http://earthobservatory.nasa.gov/Features/Victoria/victoria.php>> (accessed 02.01.10)
- Riebeek, H. (2006). Lake Victoria's falling waters. Earth Observatory Features. NASA. <<http://earthobservatory.nasa.gov/Study/Victoria/printall.php>> (accessed 28.01.09)
- Rocheleau, D., Benjamin, P., and Diang'a, A. (1995). The Ukambani region of Kenya. In J.X. Kasperson, R.E. Kasperson & B.L. Turner II (Eds), *Regions at risk: comparison of threatened environments*. New York: United Nations University Press.
- Rocheleau, D., Steinberg, P.E., and Benjamin, P.A. (1995a). Environment, Development, Crisis and Crusade: Ukambani, Kenya, 1890-1990. *World Development* 23(6): 1037-1051
- Sadoff, C. and Muller, M. (2009, August). *Water Management, Water Security and Climate Change Adaptation: Early Impacts and Essential Responses* [TEC Background Paper No, 14]. Elanders: Global Water Partnership.
- Savenije, H.H.G., and Van der Zaag, P. (2008). Integrated water resources management: concepts and issues. *Physics and Chemistry of the Earth* 33: 290-297
- Schreier, H., Bestbier, R., Brown, S., Hall, K., von Westarp, S., and Elliot, L. (2003). *Water and International Development* [CD Rom]. Vancouver, BC: Institute for Resources and Environment, University of British Columbia
- Schreier, H., Hall, K., Brown, S., Lavkulich, L., and Zandbergen, P. (2003). *Integrated Watershed Management* [CD Rom]. Vancouver, BC: Institute for Resources and Environment, University of British Columbia
- Seale, C. (1999). Quality in Qualitative Research. *Qualitative Inquiry* 5(4): 465-478.
- Simms, A. and Reid, H. (2005). *Africa: Up in Smoke*. London: International Institute for Environment and Development/NEF.
- Smit, B., Burton, I., Klein, R.J.T., and Wandel, J. (2000). An Anatomy of Adaptation to Climate Change and Variability. *Climatic Change* 45: 223-251

- Smit, B. and Pilifosova, O. (2001). Adaptation to climate change in the context of sustainable development and equity. In J.J. McCarthy., Canziani, O.F., Leary, N.A., Dokken, D.J., and White, K.S. (Eds) *Climate Change 2001: Impacts, Adaptation and Vulnerability [Contributions of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change]*. Cambridge, UK: Cambridge University Press.
- Smit, B. and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16: 282-292.
- Smith, J.B. (1996). Development of Adaptation Measures for Water Resources. *International Journal of Water Resources Development* 12(2): 151-163
- Smith, J.B., Ragland, S.E. and Pitts, G.J. (1996). A Process for Evaluation Anticipatory Adaptation Measures for Climate Change. *Water, Air and Soil Pollution* 92: 229-238
- Speranza, C.I., Kiteme, B. and Wiesmann, U. (2008). Droughts and famines: The underlying factors and the causal links among agro-pastoral households in semi-arid Makueni district, Kenya. *Global Environmental Change* 18: 220-233.
- Steduto, P. and Kuylensstierna, J. (n.d.). *Climate change, energy and food security, economic development – in the end, it all trickles down to water*. CLIMATE-L.ORG Bulletin
- Steins, N.A., and Edwards, V.M. (1999). Collective Action in Common-Pool Resource Management: The Contribution of a Social Constructivist Perspective to Existing Theory. *Society and Natural Resources* 12 (6): 539-557
- Swatuk, L.A. (2005). Political challenges to implementing IWRM in Southern Africa. *Physics and Chemistry of the Earth* 30: 872-880
- Thompson, J., Porras, I.T., Tumwine, J.K., Mujwahuzi, M.R., Katui-Katua, M., Johnstone, N., and Wood, L. (2001). *Drawers of Water II: 30 years of change in Domestic Water Use and Environmental Health*. International Institute for Environment and Development, London, United Kingdom.
- Tiffen, M., Mortimore, M. and Gichuki, F. (1994). *More People, Less Erosion: Environmental Recovery in Kenya*. Nairobi, Kenya: African Centre For Technology Studies; London, UK: Overseas Development Institute.
- Tompkins, E., & Adger, W. (2004). Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change? *Ecology and Society* 9(2): 10.
- Thornton, P.K., Jones, P.G., Owiyo, T.M., Kruska, R.L., Herrero, M., Kristjanson, P., Notenbaert, A., Bekele, N., and Omolo, A. (with contributions from Orindi, V., Otiende, B., Ochieng, A., Bhadwal, S., Anantram, K., Nair, S., Kumar, V., and Kulkar, U.). (2006). *Mapping Climate Vulnerability and Poverty in Africa*. Nairobi, Kenya: Department of International Development, International Livestock Research Institute (ILRI).
- United Nations Development Program (UNDP). (n.d.). *Kenya Natural Disaster Profile*. Geneva: United Nations. <<http://www.ke.undp.org/KenyaDisasterProfile.pdf>> (accessed 15.09.09).

- United Nations Environment Program (UNEP). (2000). *Devastating Drought in Kenya: Environmental impacts and responses*. Geneva: United Nations.
- United Nations Environment Program (UNEP). (2005). *Africa environmental outlook: Past, present and future perspectives*. Geneva: United Nations.
- United Nations Environment Program (UNEP). (2006). *The 2nd World Water Development Report: Water, a shared responsibility*. Geneva: United Nations.
- United Nations – Water/Africa (UNWAfrica). (2003). *The Africa water vision for 2025: Equitable and sustainable use of water for socio-economic development*. Addis Ababa, Ethiopia: Economic Commission for Africa.
- Van Aalst, M. A., Cannon, T. And Burton, I. (2008). Community level adaptation to climate change: The potential role of participatory community risk assessment. *Global Environmental change* 18: 165-179
- Virgo, P. (2009, December). Chad: Drying, Drying, Disappearing. *Inter Press Service*. AllAfrica Global Media. <<http://allafrica.com/stories/200912270080.html>> (accessed 15.01.10)
- Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G.D., and Pritchard, R. (2002). Resilience Management in Social-ecological Systems: a working hypothesis for a participatory approach. *Ecology and Society* 6(1)
- Walker, B., Holling, C., Carpenter, S., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecology and Society* 9 (2): 5.
- Walker, B., & Salt, D. (2006). *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, DC: Island Press.
- Wamalwa, B.N. (1989). *Indigenous knowledge and natural resources*. In Kiriho, A. and Juma, C. (Eds), *Gaining ground: Institutional innovations in land-use management in Kenya*. Nairobi, Kenya: African Centre for Technology Studies
- White, G.F., Bradley, D.J. and White, A.U. (1972). *Drawers of water*. Chicago, University of Chicago Press.
- WWF. (2008, March). Africa bears the brunt of climate change. WASH news Africa. <<http://washafrika.wordpress.com/2008/03/18/africa-bears-the-brunt-of-climate-change-wwf/>> (accessed 15.01.10)
- Personal Communication*
- Kamwanza, M. (2009). ALRMP. Government of Kenya, Makueni District. March 26, 2009.
- Kanyiva, J. (2009). Community Mobilization Officer, ALRMP. Government of Kenya, Kitui District, March 18, 2009.
- Kimwilu, F. (2009). Community Organizer with SASOL, Keutunda sublocation, Kitui District, February 19, 2009

- Mbaa Kimei Self Help Group, Nthongoni Village, Sakai Sublocation, Makueni District. March 28, 2009
- Muendo, B. (2009). SASOL Technical Supervisor, Keutunda sublocation, Kitui District, February 22, 2009.
- Mukuna, R., Musaali, M., Ndambo, J., and Ngula, J. (2009). Village Elders: Nthongoni, Muiui, Kathamba, Kiteani. Sakai Sublocation February 25, 2009.
- Mukusya, J. (2009). Co-founder of Excellent Development. Kola, Kenya. January 22, 2009.
- Mulonzi, D. (2008) Gender and Social Development Officer. Government of Kenya, Makueni District. December 17, 2008.
- Muoma, J. (2009). Program Coordinator, Kitui Development Centre, Kitui town, Kenya. March 18, 2009.
- Musyoka, B. (2009). District Drought Management Officer, ALRMP. Government of Kenya, Kitui District. March 18, 2009.
- Mutaki, V. (2009). District Agricultural Officer. Government of Kenya, Mbooni District. March 31, 2009
- Mutisya, D. (2009). Assistant chief of Kyangunga sublocation, Government of Kenya, Kitui District. February 23, 2009.
- Mutiso, G-C. M. (2009). Chairman of SASOL foundation, Thika, Kenya. February 22, 2009.
- Mutonga (2009). District Water Officer, Ministry of Water and Irrigation, Government of Kenya. January 26, 2009.
- Mutua, K.(2009). Chief Manager Tanathi Water Service Board. Government of Kenya, Kitui District. March 18, 2009.
- Nakiyu, J. (2009). Water Rights Officer, TANATHI Water Resources Management Authority, Government of Kenya, Machakos, Kenya. April 15, 2009.
- Ndeto, F. (2009). District Water Officer, Government of Kenya, Mbooni District. March 31, 2009.
- Ndiku, D. (2009). Assistant chief of Sakai. Government of Kenya, Makueni District. January 27, 2009.
- Olago, D. (2009). Professor, Department of Geology, University of Nairobi, Nairobi, Kenya. January 7, 2009.
- Ouma, G. (2009). Professor, Department of Meteorology, University of Nairobi, Nairobi, Kenya. January 7, 2009.
- Tei Wa Aka Ma Musyi Women's Self Help Group, Muiui Village, Sakai Sublocation, Makueni District. March 30, 2009.

Tukus, P. (2009). Assistant chief of Keutunda, Government of Kenya, Kitui District. February 20, 2009.

Wandiga, S. (2009). Professor and Resilience project co-ordinator, Department of Chemistry, University of Nairobi, Nairobi, Kenya

8. Appendices

Appendix A – Summary of Case Study Sites

Project Institution	Increasing community resilience to drought in Makueni district' (Resilience) pilot project			SASOL (Sahelian Solutions)	
Location	Makueni district			Kitui district	
	Kisau division			Central division	Mutha division
	Waia location			Mulango location	Kanziku location
	Sakai sub-location			Kyangunga sub-location	Keutunda sub-location
	Nthongoni Village	Muiu Village	Kathamba Village	Kitundu Village	N/A
Sand dam	Kwa Mutingu	Kwa Dison	Kwa Ndeto	Kwa Ndunda	Musingu
No. of Households	128	204	143	225	215
No. Of questionnaires	13	21	14	22	22
Pop.	5000*	5000*	5000*	4000*	4410
Age of Sand dam	2	3	0	14	6

* Approximate population of the entire sublocation.

Appendix B – Seasonal prediction flyer in Kamba

VANDA MBEU ITONYA
KUMIISYA SYUA, YENDAA
MBUA NINI, ISYAA KWA MITUKI
NUNDU MBUA NI NINI
TULUNGYE NZAA NA UKYA
KUU KWITU.



Ukunikili wa mbua ya uua mwei wa
katatu kuvika wa katano 2009

*Uvoo uu usauvite'e ni mivea ya
nima, nditilya na ALRMP II
MAKUENI*

UKUNIKILI WA MBUA YA UUA

Uu niwo ukunikili wa mbua ya uua mweini wa
Katatu-Kana-Kuvika wa Katano 2009 kuu
Makueni, Mbooni, Nzau, na Kibwezi.

Ukunikili wa ivinda.

Mbua nikwikwitiw'a kwithwa yi nini mbee wa
undu yithiwa yitilye.

Mwambiliilyo wa mbua.

Mbua yikwitiwa kwambiliilya kumwa kya
keli kya mwei wa wakatatu 2009.

Kuthela kwa mbua.

Mbua nikwikwitiw'a kuthela kumwa kya keli
mwei wa Katano 2009.

Mawendesyo ma muvea wanima.

Aimi nimekulwa mokilye mitunda yoo,
masevye mivea ya kusuvia kutwawa kwa
muthanga, na maisevya mivea ya kukolania
kiw'u kutavikite matuku thanthatu mwei wa
katatu. Mbanda ya thano yaila kuthela matuku
ikumi na atano mwei wa katatu.

Kunyuya mithemba ya mbeu sya kuvanda.

1. Kwa isio ila mbumu ta (Kathonzweni,
Kilome, Nguu, Wote, Mbitini, Kibwezi, Mito
Andei, Kalawa, Matiliku, Kasikeu, Kisau na
Makindu) ve vata aini kuvanda miongo kenda
kwa yiana (90%) ya mbeu ila itonya kuumisya
munyao ta muvya, mwee, nthooko, nzau,
ndengu, vamba na mbeu ya mbemba ila ikua
ivinda ikavi.

Mithemba ya mbeu ila yathive kuvandwa:

Mbemba – KCB, DLCI, DHO1 na DHO2
Mboso – KATB1[Kathika], KATB9, KATX69
KATX56, Katumbuka[GLP92], na
GLP004,
Muvya – Gadam, Serendo na KAR1 Mtama1
Mwee – Pearl millet, PM1, PM2, PM3
Wimbi – FM1 na FM2
Nthooko – M66, K80, KVVU27-1, Ken Kunde,
KVU419
Nzau – KAT60/8, Mbaazi 1 na Mbaazi 2

Ndengu - N26 na N22

2. Isio sya iimari ta (Tulimani, Mbooni, Kilungu,
Kaiti, Kee na isio inwe sya Kilome) aimi
nimekulwa mavande miongo muonza an kwa
(75%) ya mbeu ila itonya kumisya munyao.
yiana

Mithemba ya mbeu ila yitikilitwe kuvandwa. vanda vatonyeka:-

- Miongo muonza na itano kwa yiana (75%) ya
mbeu ila syi'w'aa na mituki ta KCB, DLCI na
DHO1
- Miongo ili na itano kwa yiana (25%) ya mbeu
ila ya katikati ta DHO2 na DHO4.

Mithemba ya mbooso.

Vanda mbooso ila yiw'aa na mituki ta:-

- KATX 69
- KATX 56
- KAT Bean 9
- KAT Bean 1
- Katumbuka (GLP92)
- Mwei umwe (GLP004)

Kwa aini ala me imani utemi wa mitao niwaile
nundu wa kumaalya na kukwata kiw'u kikatwae
mianda yoo na syandani mateme mifuu ya
kumaalya kiw'u mimea yili kang'ate.

NB.

Aimi nimekulwa masuvie vamba ta muti wa
kuete mbesa isioni ila syi uini na matumoni ta
(Mbitini, Matiliku, Wote, Kisau, Tulimani, Kee,
Kaiti, Kilome kya nti na Kilungu kya itheo).

Republic Of Kenya



Uvoo kwa uliku kulya uvisi wa nima ula wi vakavi
kana

Munene wa uim[DAO] Makueni

Simu. No. 94433016.

kana

DMO/ALMP II

Simu. NO. 044-33086

kana

Nearest Agricultural Office.

Ministry of Agriculture.

Crop	Variety	Maturity Duration
Maize	KCB	105-120 Days
	DLC-1	95-115 Days
	DH 01	100-120 Days
	DH 02	120-140 Days
	DH 04	130-150 Days
	Il 5 series	150-180 Days
Beans	Others- Pioneer 3253, PAN 67	140-180 Days
	KAT Bean 1	60-65 Days
	KAT Bean 9	60-65 Days
	KAT X 56	60-65 Days
	KAT X 69	60-65 Days
	Mwitamanini	65-80 Days
Sorghum	Mwezi moja	65-80 Days
	Sereia	110-120 Days
	Serodo	110-120 Days
	KAR1 Mtama1	95-100 Days
Millet	Gadam	85-95 Days
	KAT PM1	80-100 Days
	KAT PM2	80-90 Days
	KAT PM3	75-90 Days
	KAT FM1	90-115 Days
Cow peas	KATPRO-1	65-80 Days
	M66	80-90 Days
	K 80	45-60 Days
	KVU 419	65-72 Days
	KVU 27-1	65-72 Days
Green grams	Ken Kunde	65-72 Days
	N26	60-65 Days
	N22	80-90 Days
Pigeon Peas	KAT 60/8 (MD)	130-150 days
	Mbaazi-1 (SD)	105-120 days
	Mbaazi-2 (LD)	150-180 days
Dolichos lab lab (Mtumbu)	KAT DL-1 (DL 1002) Black	80-90 Days
	DL 1009 Dirty or Cream White	95-115 Days
Cassava	KME-1	16 Months
	KME-61	14 Months
	Macerici	16 Months
	(Sweet & Tolerant to cassava Mosaic Virus)	
Cotton	HART 89 M	8-10 Months

Crop	Fertilizer/ Manure Requirement	Seed rate / Acre
Maize	FYM- 3-5 Tons /Ha Basal- NPK 20:20:0-50 Kgs / Acre Top dress- CAN- 50 Kgs /Acre	1-1 1/2 Kgs
Beans	FYM- 3-5 Tons /Ha Basal- NPK 20:20:0-50 Kgs / Acre Top dress- CAN- 50 Kgs /Acre	16-20 kgs
Sorghum	FYM- 3-5 Tons /Ha Basal- NPK 20:20:0-50 Kgs / Acre Top dress- CAN- 50 Kgs /Acre	3-4 Kgs
Millet	FYM- 3-5 Tons /Ha Basal- NPK 20:20:0-50 Kgs / Acre Top dress- CAN- 50 Kgs /Acre	2 1/2 Kgs FM1 2 Kgs FM2 2 1/2 Kgs FM3 1 1/2 Kgs FM 1 1 1/2 Kgs FM 2
Cow peas	FYM- 3-5 Tons /Ha SSP/ DAP- 25 Kgs/ Acre	8-10 kgs
Green grams & Yellow grams	FYM- 3-5 Tons /Ha SSP/ DAP- 25 Kgs/ Acre	4-7 Kgs
Pigeon Peas	FYM- 3-5 Tons /Ha NPK 20:20:0 - 25 Kgs/ Acre	8-10 kgs
Dolichos lab lab (Nzavi/Mbumbu)	FYM- 3-5 Tons /Ha Does not respond to fertilizer Can plant in poor soils	3-5 Kgs
Cassava	Occasionally add FYM, no fertilizer needed	4,000 Cuttings
Cotton	Marginal Returns to Fertilizers Black soils- 40 Kgs CAN Sandy & Red loamy soils - 60 kgs DSE/TSF/ Acre	7 Kgs

Crop	Spacing	Expected Yield/ Acre
Maize	90 x 30 cm (3 Ft x 1 Ft 1 plant/ Hole)	12-16 Bags
	90 x 30 cm (3 Ft x 2 Ft 2 plant/ per Hole)	12-16 Bags
	90 x 60 cm (3 Ft x 2 Ft 2 plant/ per Hole)	10-16 Bags
	90 x 60 cm (3 Ft x 2 Ft 2 plant/ per Hole)	12-20 Bags
Beans	Inter crop Maize: 150X 30 cm-2 rows Beans 120 X 30 cm-1 Row of beans Sorghum: 150 x 15 cm 2 rows of beans	7-9 Bags 7-9 Bags 7-10 Bags 7-10 Bags
	Pure stand 45 x 20 cm Oxen- 60 x 15 cm	14-21 Bags 15-25 Bags
	60 X 20 cm Pure stand 12 x 15 cm (1 row of legumes).	8-10 Bags 4-12 Bags
		11 Bags 7.5-20 Bags
Millet	Pure stand 60x 15cm Intercrop- 120 x15 cm 1 row of legumes.	8.4 Bags 8 Bags 10 Bags 6 Bags
	30 x 10 cm	6 Bags
	60x 20 cm	3-8 Bags
	60 x20 cm	3-8 bags
Cow peas	50 x20 cm	4-7 bags
	60 x 20 cm	3-7 Bags
	45 x 15 cm	6-7 bags
		4-6 Bags
Green grams Yellow grams		
Pigeon Peas	50x 10 cm	15 Bags 2 seasons
	75 x 50 cm	9 Bags 2 seasons
	100 x 50 cm	6 Bags
	100 x 50 Cm Pure stand Intercrop- 1 row in between sorghum or Maize	13-18 Bags 11-13 Bags
Cassava	1 x 1 M	8-11 Tons
		8-12 Tons
		8-11 Tons
Cotton	100 x 30 cm 4-5 Seeds / Hole later thin to 1	1,000 Kgs

Appendix C – Household questionnaire

The questionnaires were developed with the aid of project leads and research assistants to ensure they were culturally appropriate. This also certified that the intended meaning of the questions could be translated adequately to elicit appropriate responses. The sampling method employed the strategy used by Rempel et al (2005) where households²⁴ were stratified into three groups: near the dam site, an intermediate distance from the dam site, and the outer range of the community. Within these categories 10 percent of the households were randomly sampled resulting in a total of 92 households being interviewed, with an average of 18 households per sand dam project. Respondents ranged in age between the 15-24 years to the over 75 year category, with the majority of respondent between the ages 25 – 44 years.

A challenge presented from personally administering the questionnaire were the loss in participant confidentiality and the potential for participant bias. A certain amount of confidentiality was lost according to some of the participants by answering the questions directly to me as opposed to anonymously writing answers on the questionnaire. This may have resulted in the participants being less candid and perhaps less willing to make negative comments as they saw me as affiliated with the projects. In contrast some participants appeared to be embellishing their responses, possibly hoping that the community might have a better chance of benefitting. In other cases there may have been some participants who answered according to what they believed I wanted to hear, believing perhaps that there was a right answer and a wrong answer.

The oral administration, as well as the broad, open-ended nature of many of the questions resulted in lengthy household visits. A translator facilitated a dialogue between myself and the participant, posing the questions in Kikamba²⁵ and translating the participants reply. Ample time was provided for me to record responses and to ask follow-up questions. The manner in which the questionnaires were conducted seemed culturally appropriate as Kambas are very social, often whole families and neighbours would join in, creating lively discussions and providing insight into community dynamics. And as the literacy rate in the community was unknown, by administering the questionnaire orally the participation of all those interested could be ensured.

Questionnaire: Evaluating community capacity to organize sand dam development and management

District	Division	Location	Sub-location	Village
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Gender of respondent: Female Male

Part One: Socio-economic background data

1. How long have you lived in this sub-location?

²⁴ Households were defined as all individuals eating from the same food source. Therefore one household might include one or more families depending on whether or not they all eat food from the same shamba (farm). This is the same definition employed by the Government of Kenya and allows for comparison.

²⁵ Kikamba is the language spoken by the Kamba tribe. All three translators also spoke the national language of Kiswahili if participants preferred.

2. How many households are in the village?

3. What is your age?

15-24 Years	25-34 Years
35-44 Years	45-54 Years
55-64 Years	65-74 Years
75 and Above Years	

4. What level of education have you completed?

5. How many individuals are living in your household?

How many are: Female _____ Male _____

0-5 years	6-10 years
11-15 years	16-20 Years
21-30 years	31-40 years
41-50 Years	51-60 years
60-70 years	Over 70 years

6. What is your occupation?

7. Do you do any of the following income generating activities?

Farming	Crafts (pottery, jewellery, wood carving)	Basket Making	Charcoal burning
Fruit Selling	Vegetable Selling	Brick making	Other
Shop keeping	Water selling		

8. If a farmer, how much land does your household have access to? And how much livestock

Size of Land (acres)		Livestock	
Less than one	1-5	1	2-5
6-10	11-15	6-10	10-15
20-30	31-40	16-20	21-25
41-50	Over 50	26-30	More than 30

9. Do you have any donkeys?

10. What do you grow?

11. Have you been able to grow anything **new** since the sand dams were built?

12. Do you own the land, you are cultivating?

13. How best would you describe your average monthly income?

0 – 1000 Ksh	1000-2000 Ksh	2000-3000 Ksh
3000-4000 Ksh	4000-5000 Ksh	>5000 Ksh

14. Has your monthly income improved since the sand dam was built? Explain.

Part 2: Water Background data

15. Does your household have access to enough good quality fresh water?

16. How much water did your household use per day **before** the Sand dam and **after** the Sand dam?

Less than 1 litre	1-5 litres	5-10 litres	10-15 litres
15-20 litres	20-25 litres	25-30 litres	30-35 litres
35-40 litres	40-45 litres	45-50 litres	50-60 litres
60-70 litres	70-80 litres	80-90 litres	90-100 litres
100-150 litres	150-200 litres	200-250 litres	250-300 litres

300-350 litres	350-400 litres	400-500 litres	> 500 litres
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17. What were your sources of water for domestic use **BEFORE THE SAND DAM**?

Rivers/Streams		Taps	Shallow Wells
Rainwater harvesting	Boreholes	Water Kiosk	Lakes

18. What are your main sources of water for domestic use **now**?

Rivers/Streams	Sand dams	Taps	Shallow Wells
Rainwater harvesting	Boreholes	Water Kiosk	Lakes

19. What are the main challenges/problems in the village?

20. What solutions can you suggest to solve some of the problems in your community?

21. What/who are the causes of water resource challenges/problems in the village? (climate change, lack of trees, population)?

22. Who/what is the cause of lack of rains? GOD CLIMATE CHANGE GOVERNMENT OTHER

23. Who collects the water in your household?

24. How do you collect the water?

25. Do any children collect water?

26. How many hours did you spend and how far did you walk a day collecting water before the sand dam? And now?

Before Sand Dam: _____ Hrs _____ Km

After Sand Dam: _____ Hrs _____ km

Part Three: The Sand Dam Project

27. Who initiated the sand dam?

Government	NGO	Local People	Do not know
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28. How did they start the project? (e.g. contact elder, have baraza, have training)

29. What were the reasons the project was successful?

30. To what extent were the local people involved in:

a) Initiating the project?

Large amount	Medium amount	Small amount	None	Not sure
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b) Planning the project?

Large amount	Medium amount	Small amount	None	Not sure
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c) Funding the project?

Large amount	Medium amount	Small amount	None	Not sure
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d) Managing the project?

Large amount	Medium amount	Small amount	None	Not sure
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31. Who funded the construction of the sand dam?

Government (departments?)	NGOs
Local People	Do Not know
Others	

32. If there is a problem with the sand dam, who is responsible to fix it?

Government (departments?)	NGOs
Local People	Do Not know
Others	

33. Who does the sand dam belong to?

Government (departments?)	NGOs
Local People	Do Not know
Others	

34. Did the whole community help build the sand dam?

35. Were there any challenges with the building of the sand dam?

36. Can you think of any solutions to those problems?

37. What was your role in the sand dam building?

38. Were you happy to be involved? **OR** Why did you choose to not be involved?

39. How was the sand dam committee selected?

40. How has the sand dam improved your life?

41. What are some of the other good or bad things about the sand dam project?

42. Is there more than one sand dam in the area? How many?

43. Are there any problems between the people using the one sand dam and the people using the other sand dams? If so, please describe what kind of problems.

44. Is there enough water for both sand dams? Why or why not?

45. How many people use the sand dams?

Part Four: Community Management and Participation

46. How does the community manage their water resources? Is there a committee? What are the rules and regulations?

47. How does the community repair the dam?
48. Can everyone access the sand dam?
49. Do cows and goats have access to the sand dam?
50. Does the community maintain records of water users? And how much they use?
51. Who other than ARLMP or SASOL is involved in water management in your area?
Government – which departments
NGO's – which ones
Local community groups – which ones
Not sure
52. Do women have equal decision making power in the community?
53. Do all community members have equal decision making power?
54. Are you involved in any other self-help groups? Which ones, what do they do?

Appendix D – Focus group discussion hand-out

Sand Dam Committee Focus Group Program

1. Prayer
2. Introductions
3. Explanation of research objectives and program for the morning.
4. Signing of consent forms
5. Water Sources Mapping Exercise
6. Group Discussion
7. Group Picture
8. Tea

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This research forms part of larger projects by researchers from SASOL, the Arid Lands Resource Management Project (ALRMP) and from the University of Nairobi. The goal of this particular part of the project is to identify how communities are able to manage scarce water resources, specifically through the use of sand dam technology. I am looking at the factors impacting community organization and the successful or unsuccessful management of sand dams in Kitui and Makueni districts. I am a student at York University in Canada and am studying integrated water resource management. The information I will collect and the process of collection is part of my educational training and Master's of Environmental Studies major paper research. Overall, the purpose of the project is to identify ways that similar projects can improve their implementation and help the communities to be able to equitably manage their water resources.

The research methods used will be a household questionnaire, informal interviews, personal observation and focus group discussions with sand dam committee members and other village leaders. As a resident of this local community you are invited to participate. If you feel that you have more information to contribute please feel free to contact me. The responses will guide my understanding of how individuals in the community understand how water is managed, the roles and responsibilities of different groups and whether any organizations are involved in helping the community.

Your participation in this study is voluntary and you may decide to not participate at any time. If you agree to participate, all the information you provide is confidential and your privacy will be protected to the maximum extent allowable by law. Your name, audio recordings and any other information you provide will not be connected to your identity in any written reports about this study. If you agree to allow the interviews and answers to the questionnaire to be audio recorded your name will not be recorded on the tape, these tapes will be kept secured until transcribed and destroyed. Your decision to volunteer or to stop participating at any time during the study will not influence your relationship with the research team, York University, SASOL, ARLMP, the University of Nairobi or any other group associated with the project.

The investigators and research team will be the only persons with access to the information provided during the interviews. Your participating in this study is expected to have minimal risks as your identity will only be known by the investigators. Possible benefits from participating in this research include identifying community strengths and weaknesses in managing water resources with the aim of improving the process.

If you have any concerns or questions about your participation or about the study, please contact me

Focus group discussion guide

1. What are the main water resource problems in the area? What efforts are in place to harvest, protect and conserve the resource?
2. What have been the impacts of climate change on your communities?
3. What kind of vision do you have for your community in the future?
4. How does your community (sub-location) organize? Is there a community development committee?
5. How did you first hear about the sand dam project? How was the project explained to you? How were the potential benefits described to you?
6. Is the sand dam functioning and benefiting the community as expected? Why or why not?
7. How many community members use the sand dam? What are the primary uses for the dam?
8. What are the good impacts of the sand dam? What have been the bad impacts from the dam?
9. Why was it important for you to participate in the project? What was good about being involved? What was bad or hard about being involved?
10. Was the community involved in all stages of the project: selecting the technology, planning the construction, selecting the site for the sand dam, building the sand dam, managing the sand dam?
11. How did your community organize to construct the sand dam?
12. Were there any problems during the construction of the sand dam? How were they solved?
13. How is the community planning on managing, conserving and protecting the sand dam?
14. Were there any training associated with the building of the sand dam such as on natural resource management; project management or on how to improve water quality?
15. Do you feel as if you had enough contact with and support from the people running the project? Who are they and how do you contact them?
16. What **factors** and what kind of **methods** did you use so that you were successful?
17. Has the sand dam project enabled the community to unite and organize to start other projects? Why or Why not?
18. Was the community able to make contacts with NGO's or Government Departments or Communities involved in other water management projects through the sand dam project?
19. Overall from the whole experience what were some lessons that you've learned, yourself and as a community?